Warming and acidification of the Mediterranean Sea

Jean-Pierre Gattuso
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Global carbon budget (2003-2012)

0.8 Pg C yr^{-1}

+

9.4 Pg C yr^{-1}

(9.9 Pg C in 2013)

8.6 Pg C yr^{-1}

Le Quéré et al. (2013)

Global carbon budget (2003-2012)

0.8 Pg C yr^{-1}

+

8.6 Pg C yr^{-1}

9.4 Pg C yr^{-1}

(9.9 Pg C in 2013)

Atmosphere
46%

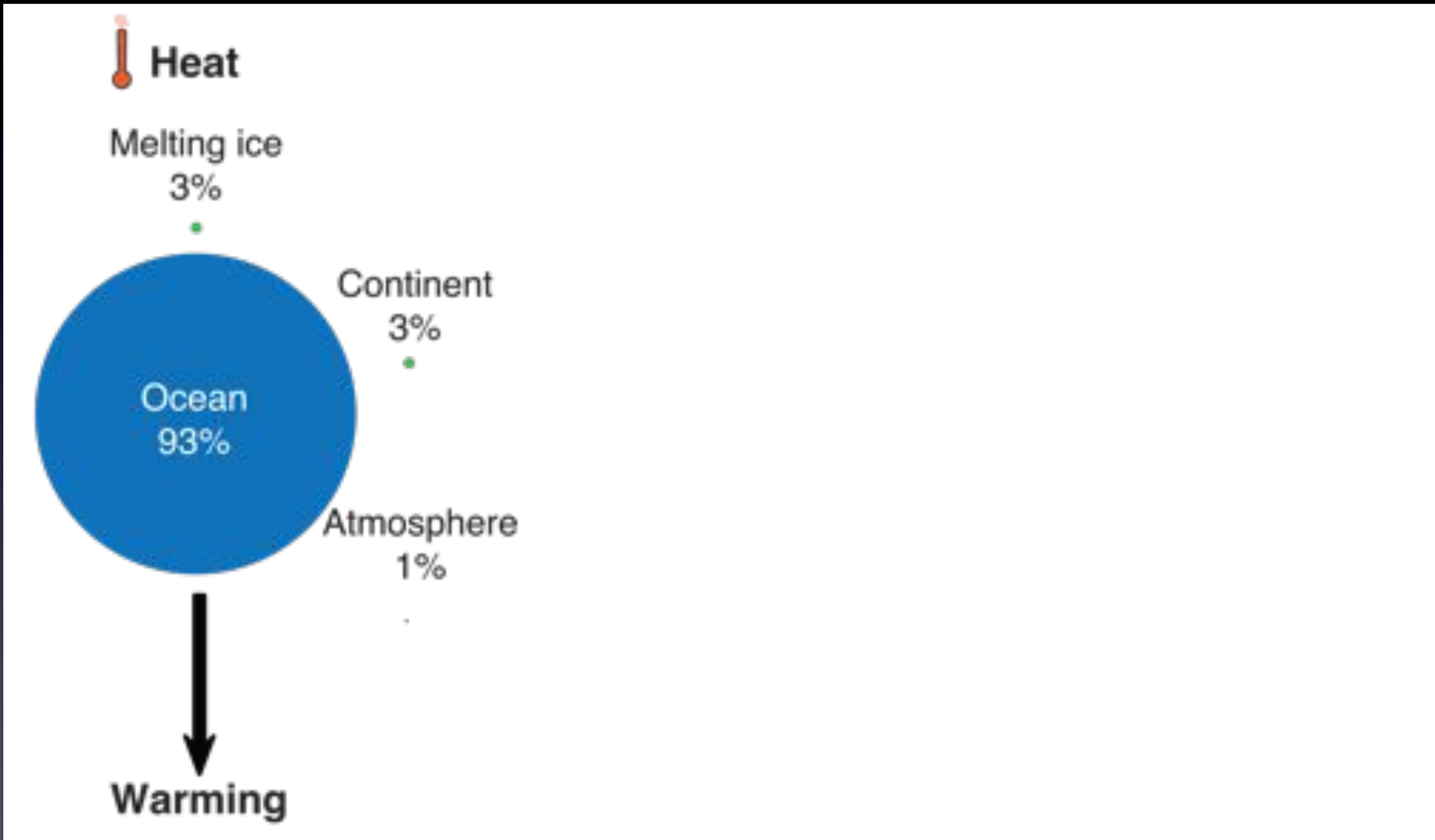
Vegetation
28%

Oceans
26%

26 millions tonnes CO_2 per day

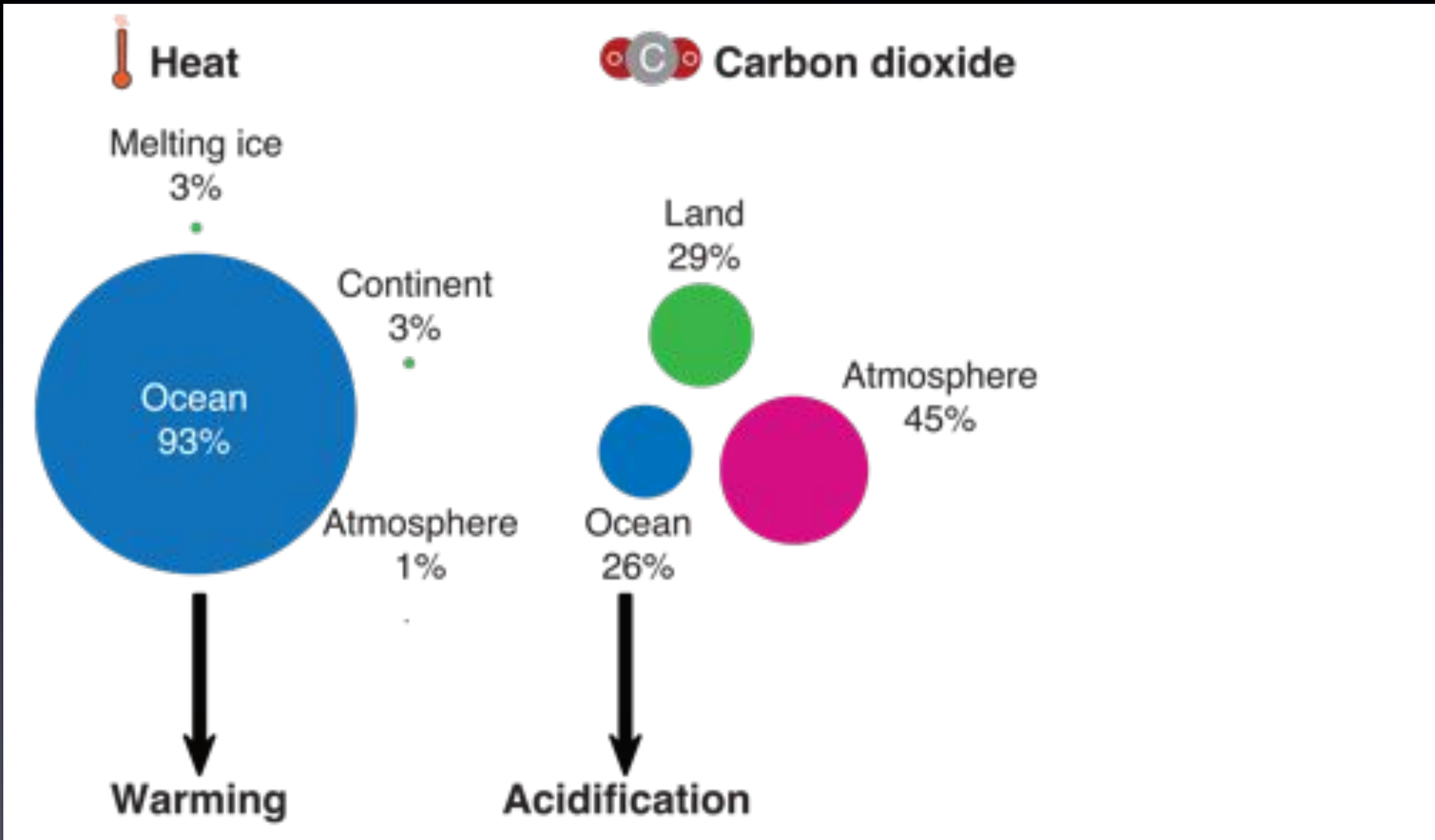
Le Quéré et al. (2013)

Ocean: actor and victim of climate change



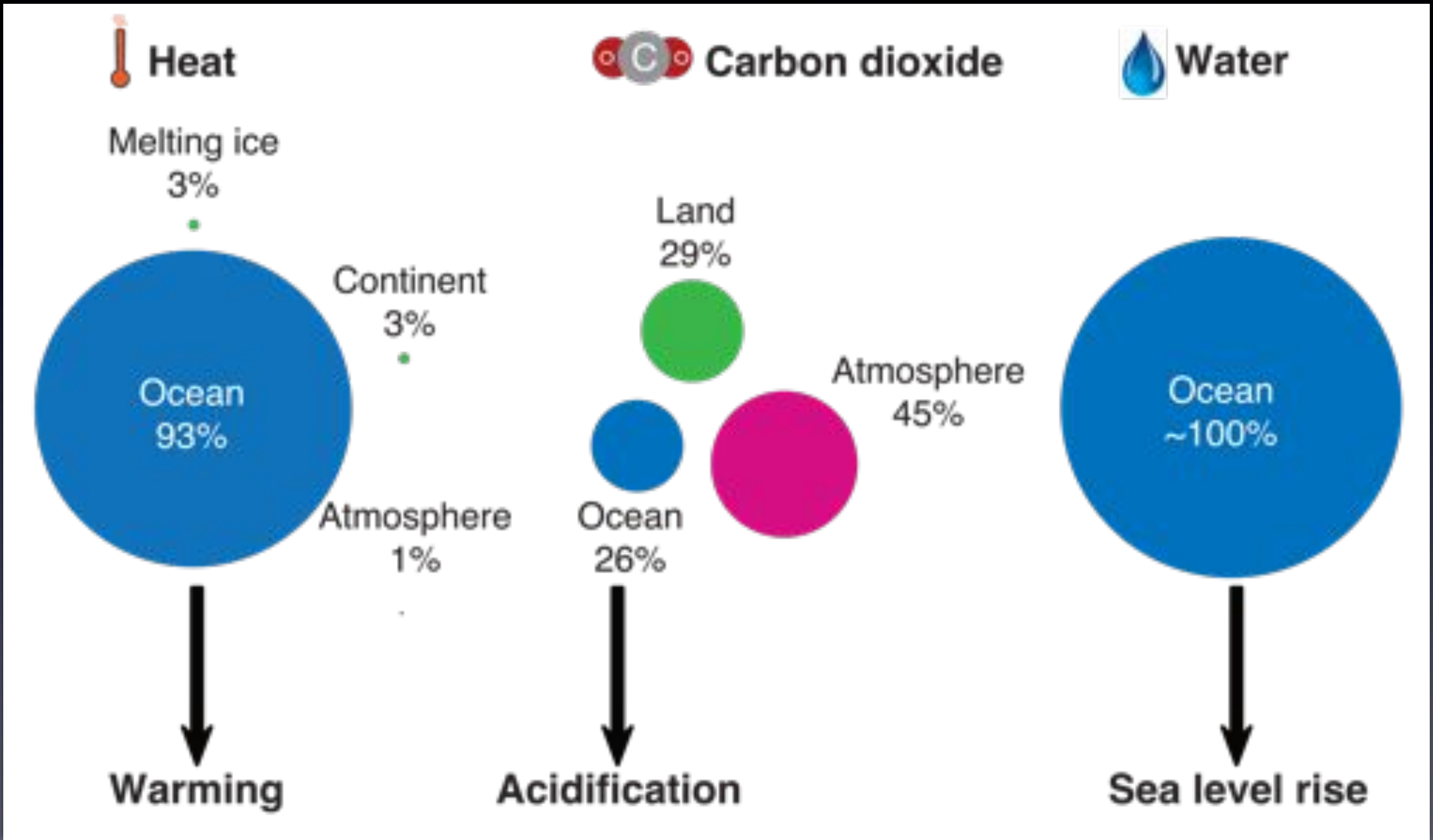
Magnan et al. (2015)

Ocean: actor and victim of climate change



Magnan et al. (2015)

Ocean: actor and victim of climate change

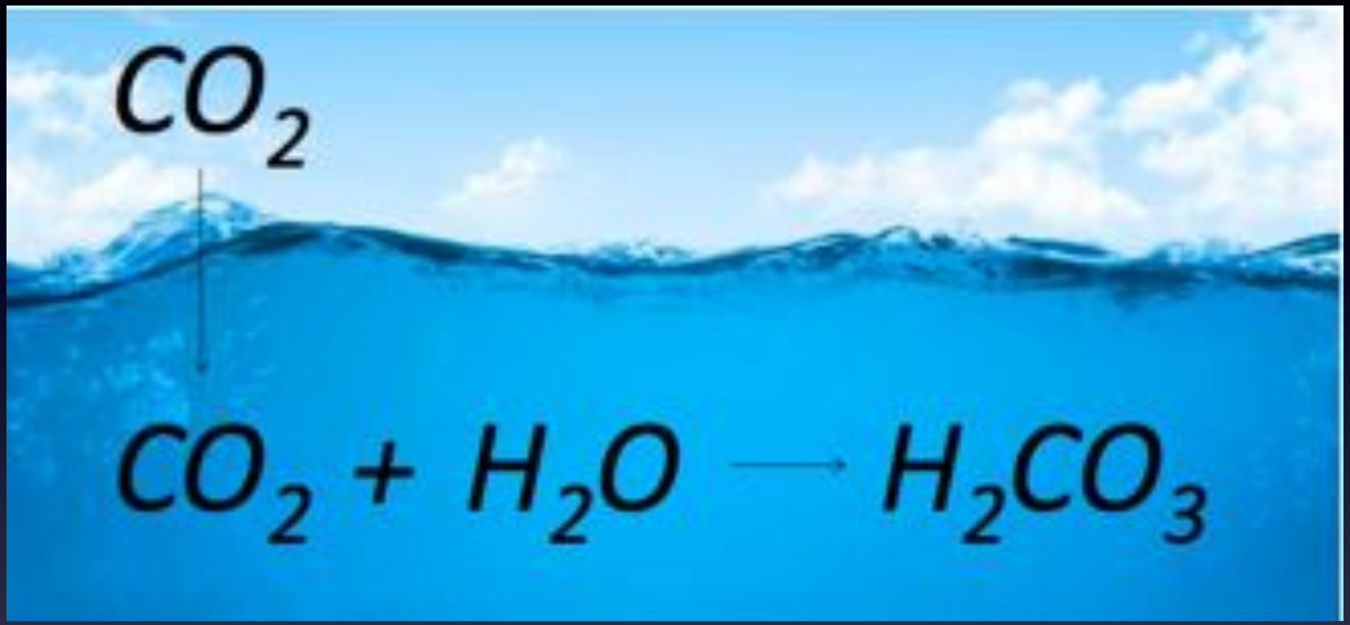


Magnan et al. (2015)

Ocean acidification

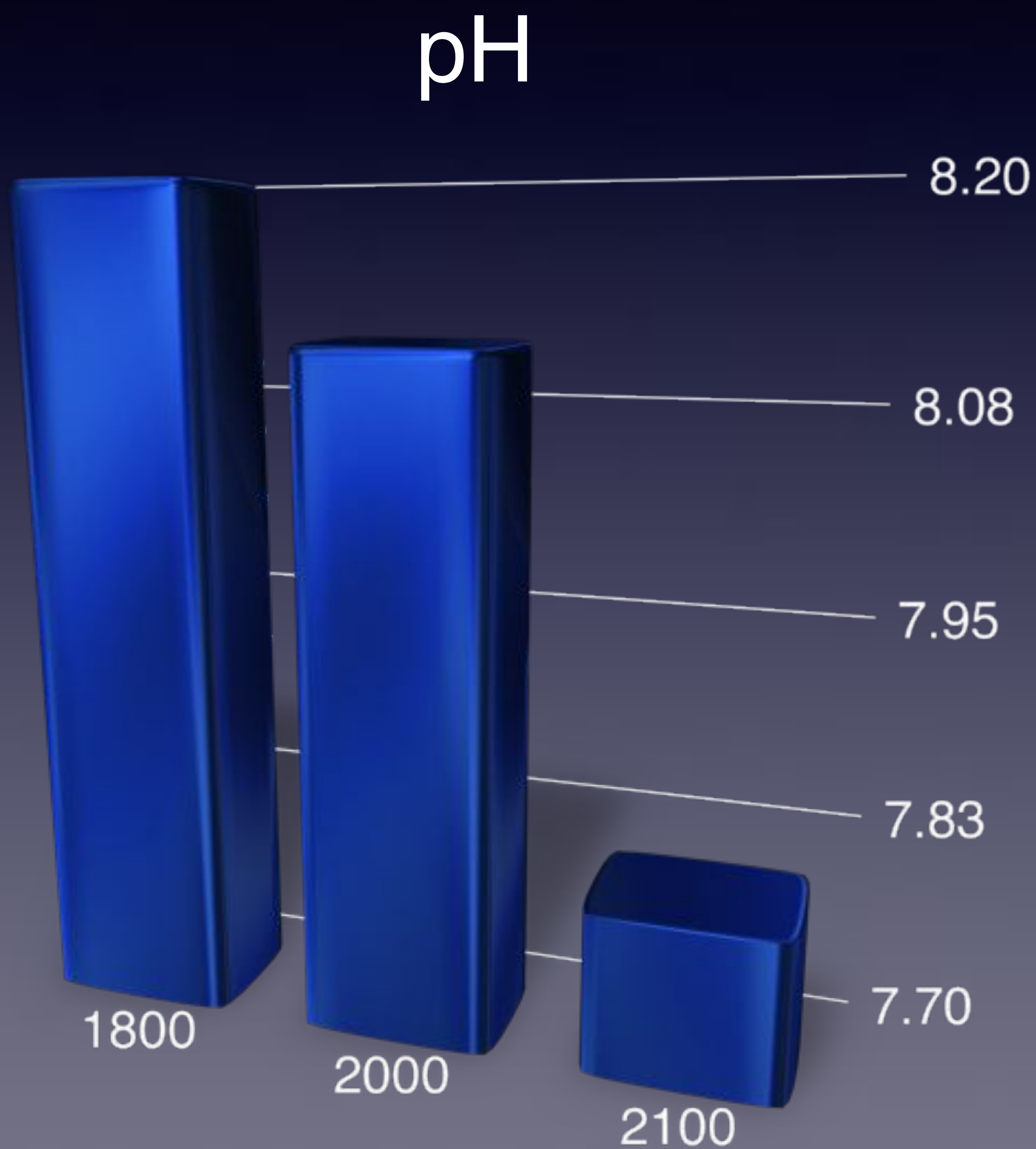
What is ocean acidification?

- CO_2 is an acidic gas (it produces an acid when combined with water)
- Each of us adds 4 kg eq CO_2 per day to the ocean (increasing acidity, reducing pH)

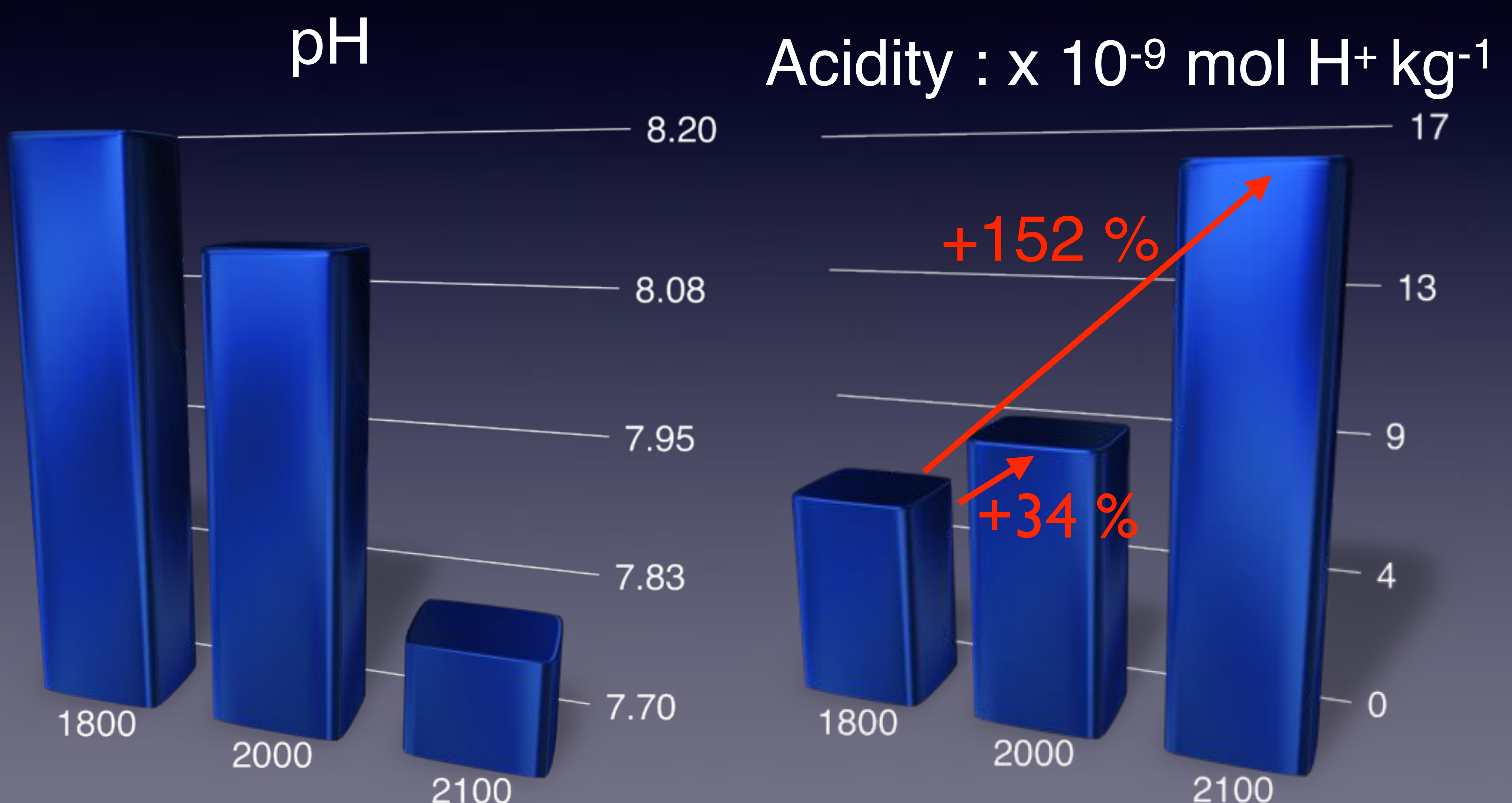


Sam Dupont

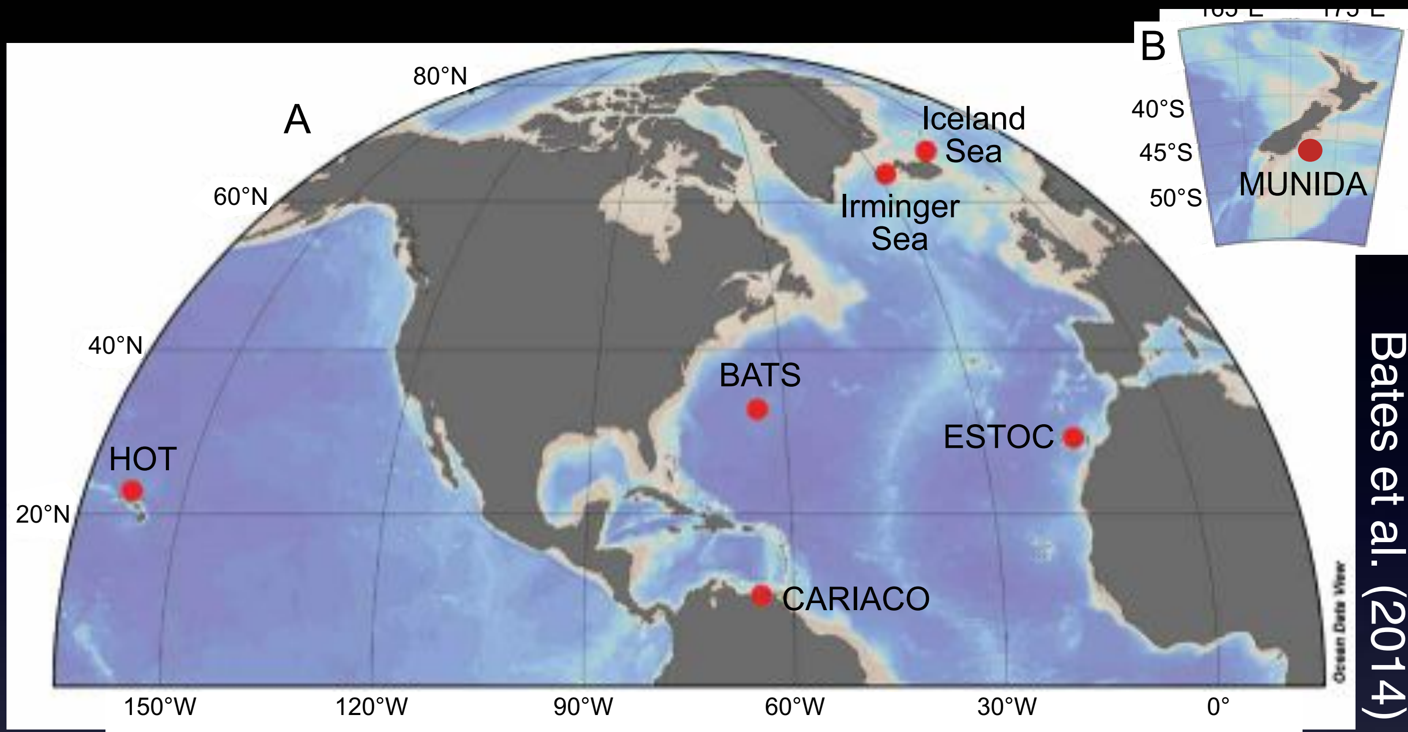
pH and acidity



pH and acidity

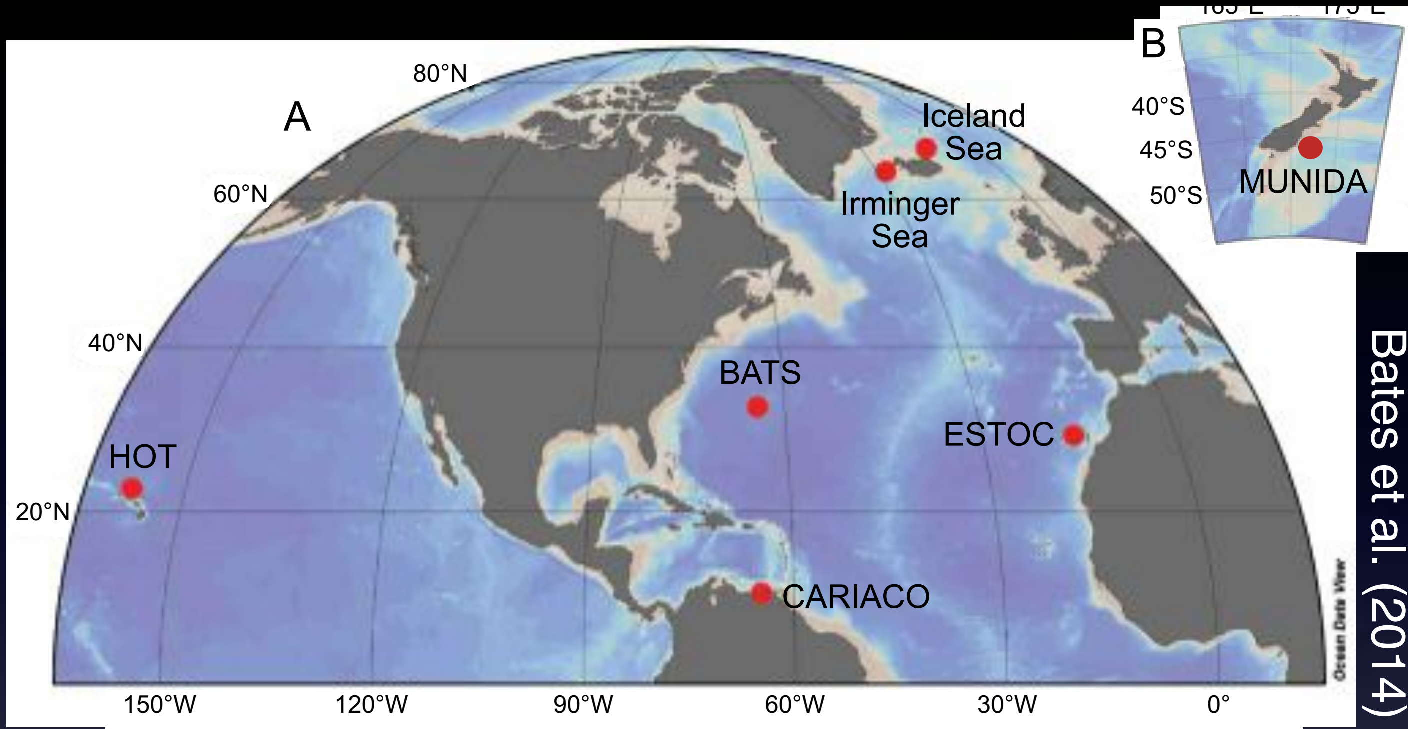


Ocean acidification can be measured

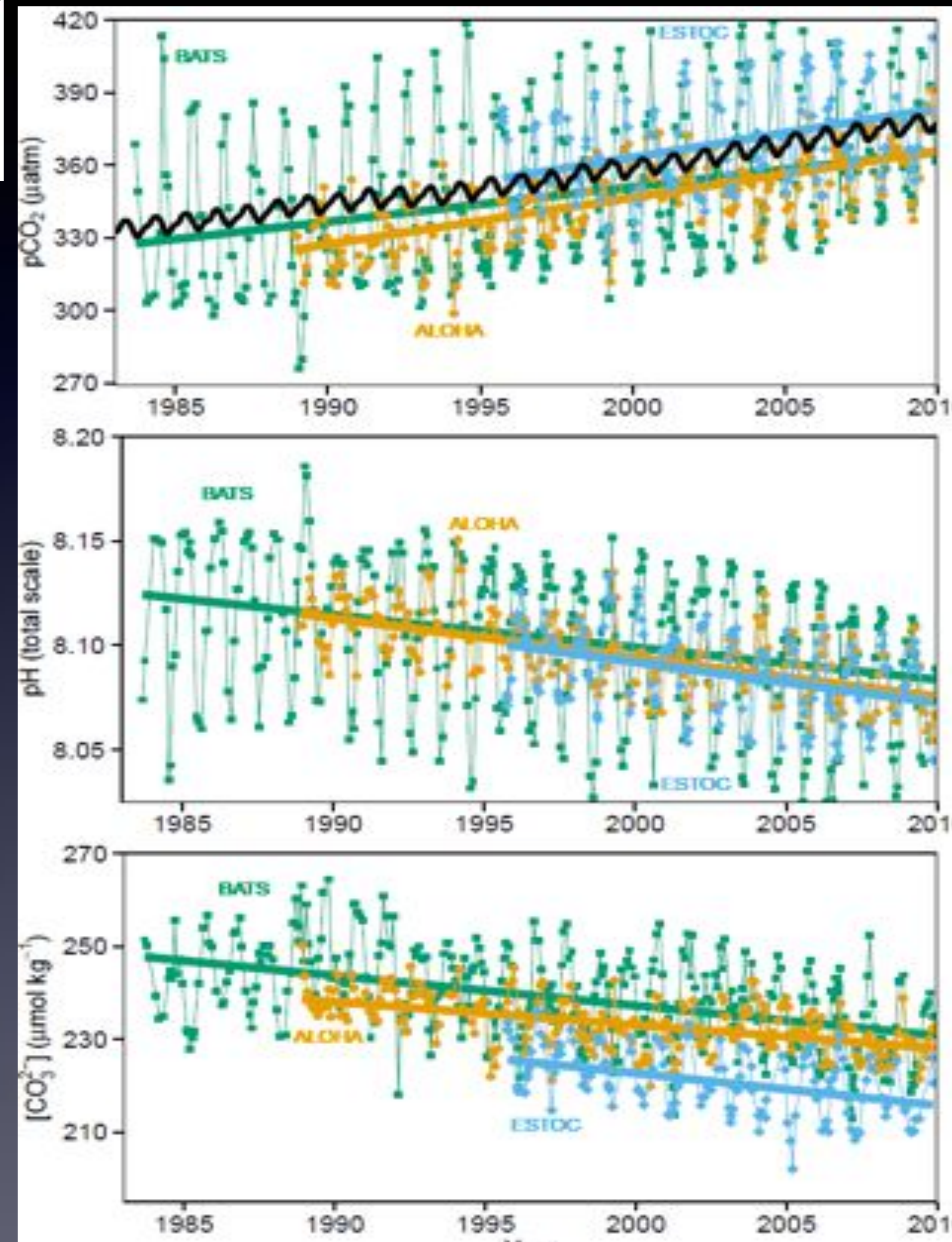


Bates et al. (2014)

Ocean acidification can be measured



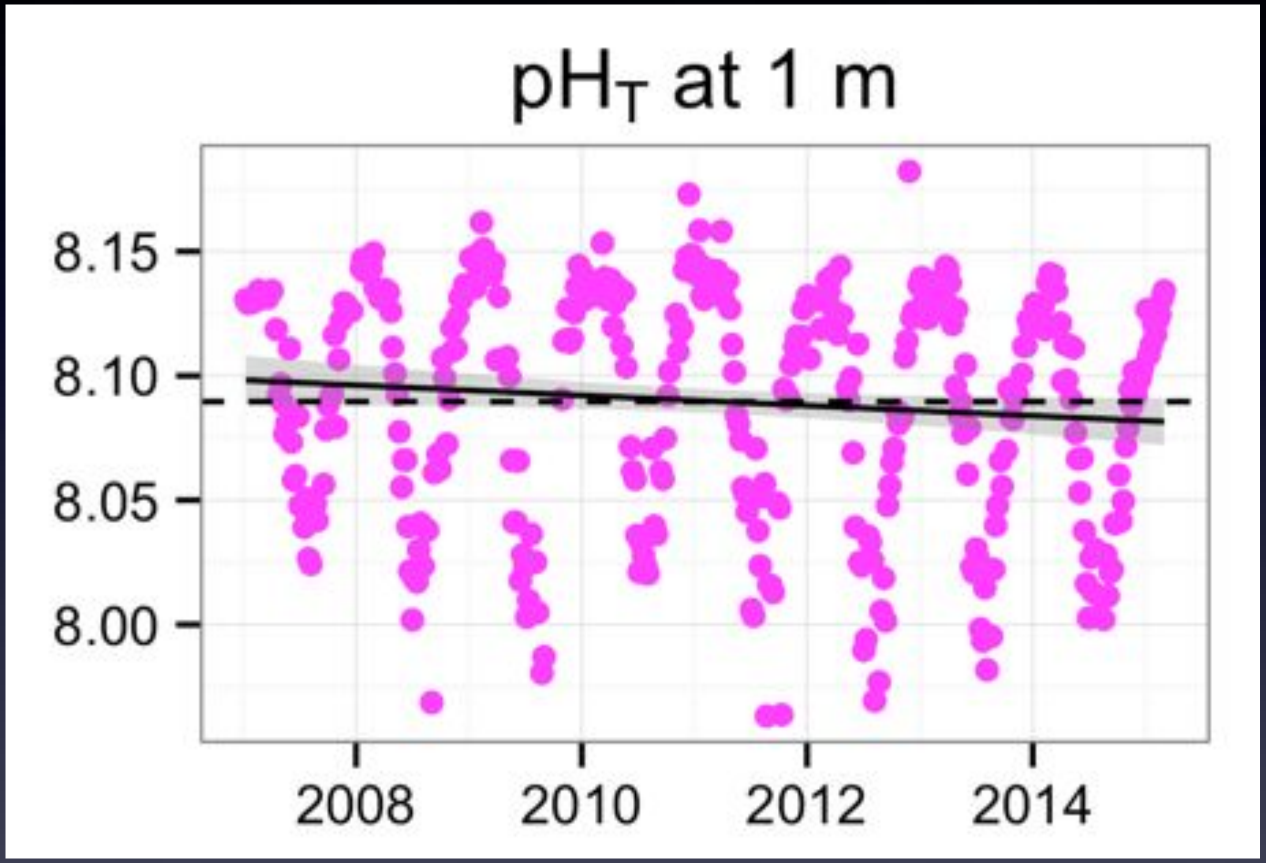
Bates et al. (2014)



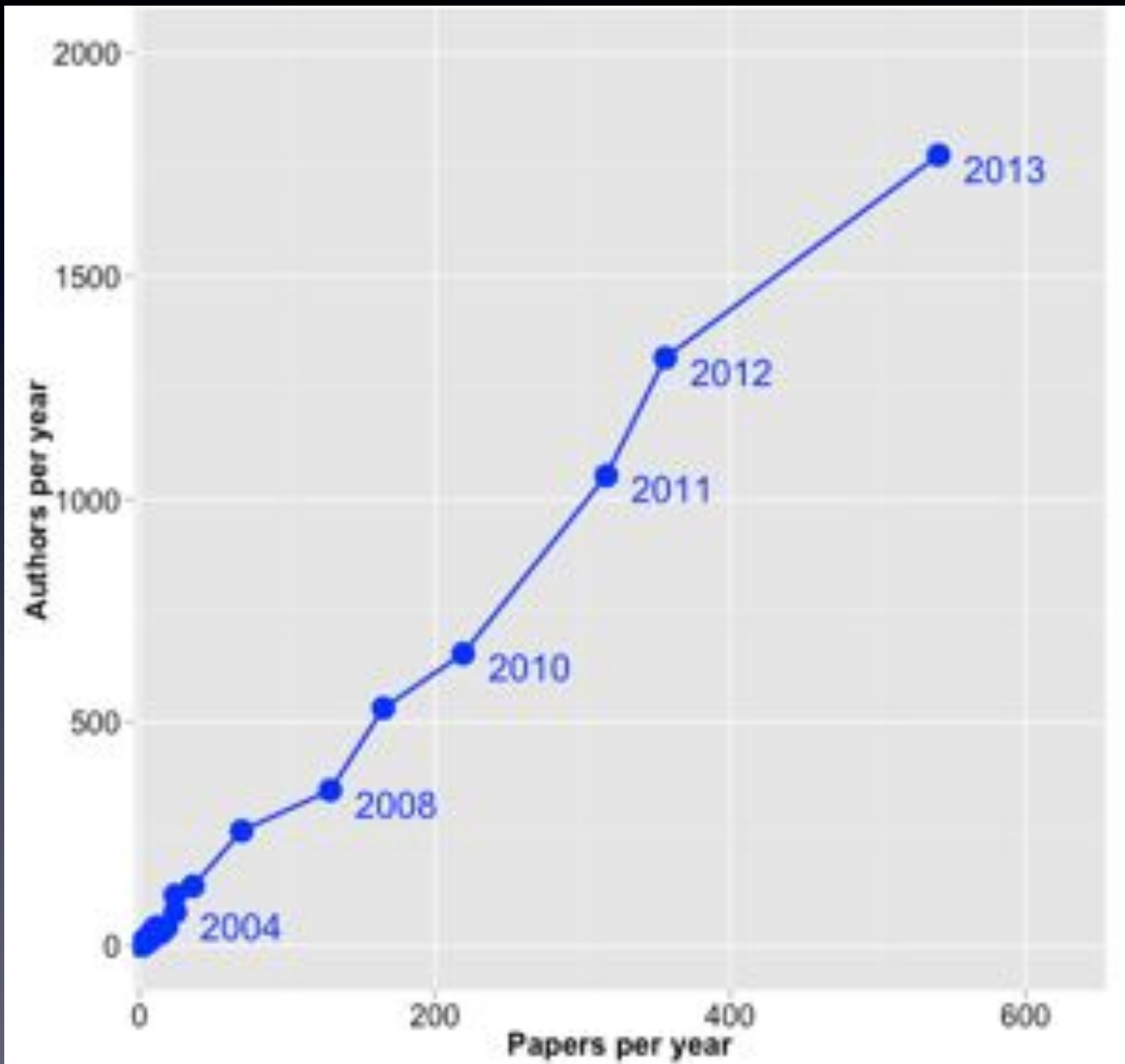
IPCC AR5 WG I

Range 1995-2009:
-0.0015 to -0.0022 units yr^{-1}

Time-series NW Mediterranean



Publication rate



Gattuso & Hansson. OA-ICC

Papers:

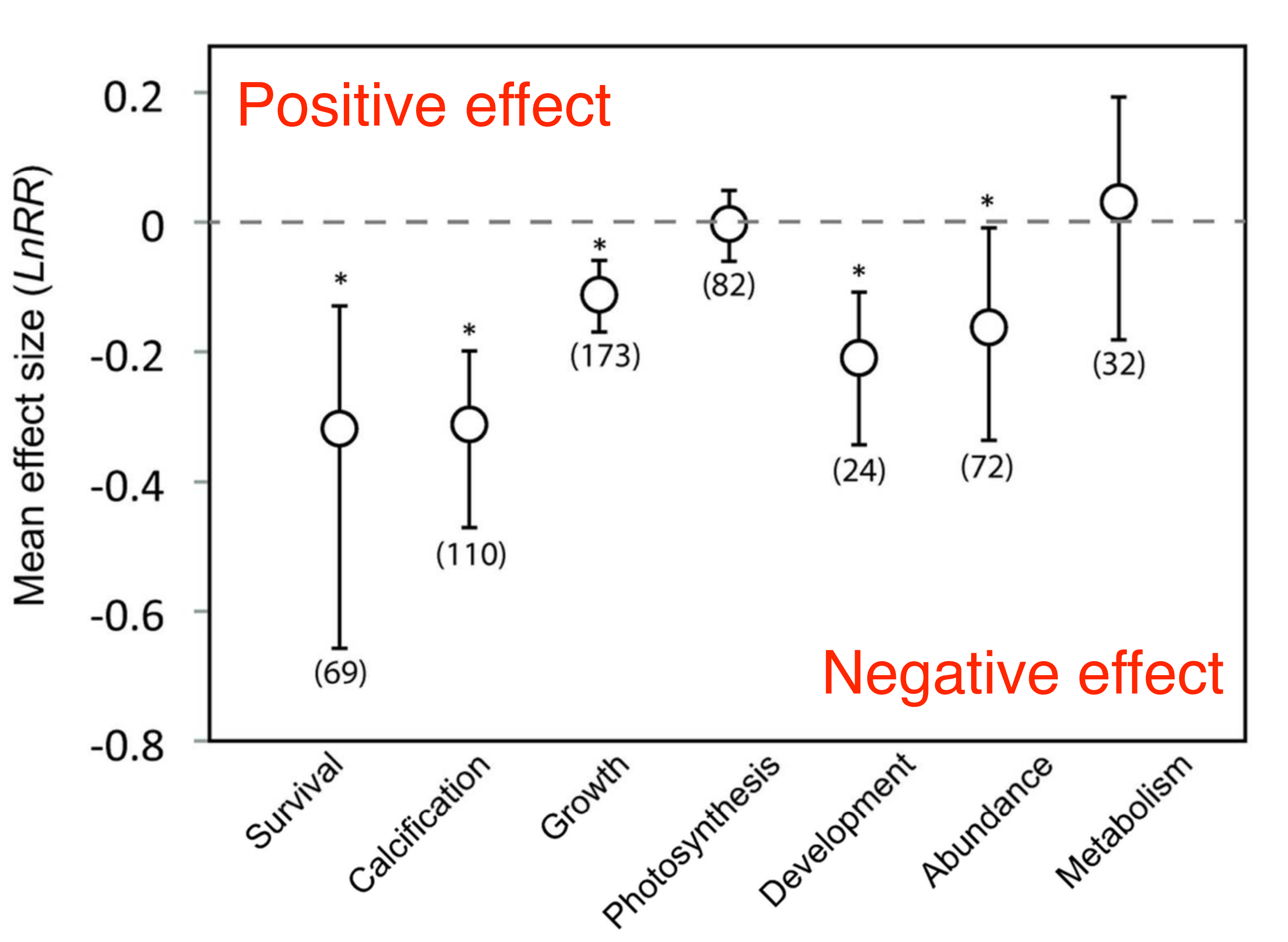
- 561 in 2013
- 50% in past 3 years
- +39% y^{-1} since 2000 vs +5% y^{-1} in WoS

Authors:

- 1804 in 2013

Meta-analysis: Kroeker et al. (2013)

- Significant negative effect on:
  - survival
  - calcification
  - growth
  - development
  - abundance



Kroeker et al. (2013)

Changes to organisms and ecosystems

Changes to organisms and ecosystems

- Reduced shell and skeleton production
- Changes in assemblages, food webs, and ecosystems
- Biodiversity loss
- Changes in biogas production and feedback to climate

(WGII 5.4.2. 6.3.2, 30.5)

Gattuso et al. (2014)

Changes to organisms and ecosystems

Gattuso et al. (2014)

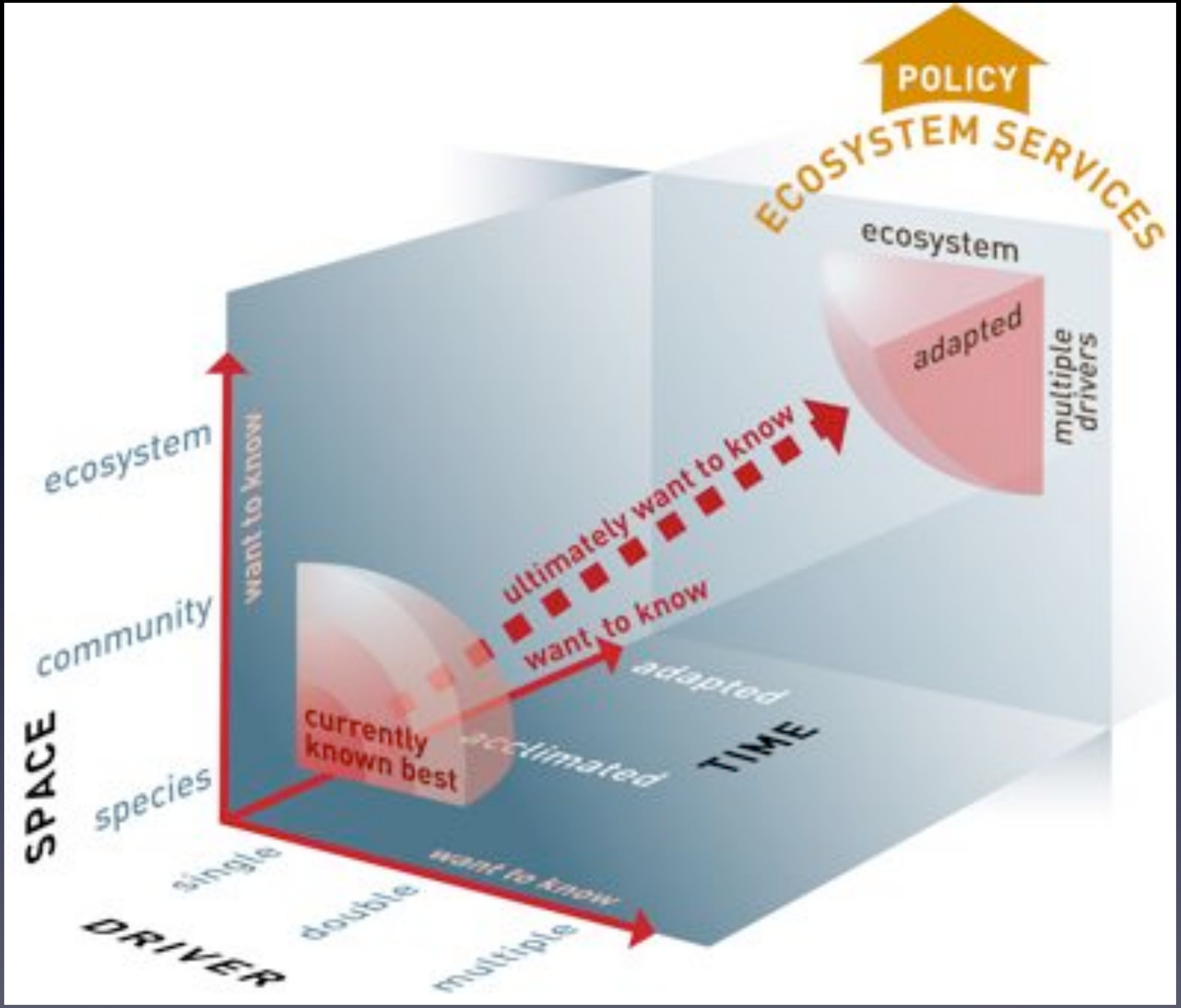
- **Biological and ecological effects**: high to low confidence
- **Biogeochemistry**: medium to low confidence

Changes to organisms and ecosystems

Gattuso et al. (2014)

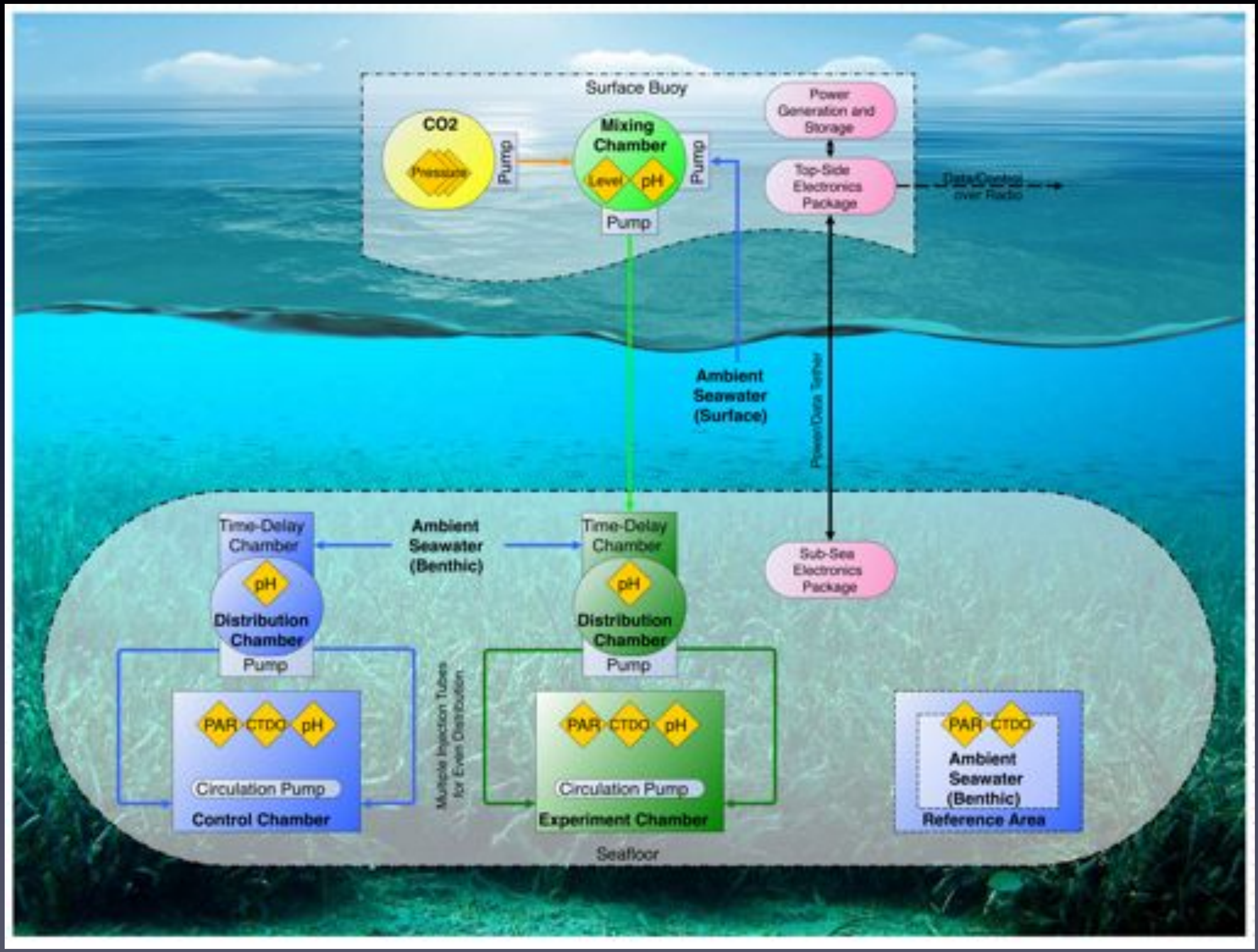
- **Biological and ecological effects**: high to low confidence
- **Biogeochemistry**: medium to low confidence
- **Knowledge gaps**:
  - Multiple drivers
  - Evolutionary adaptation
  - Response of communities
  - Food web, up to predators

Experimental space

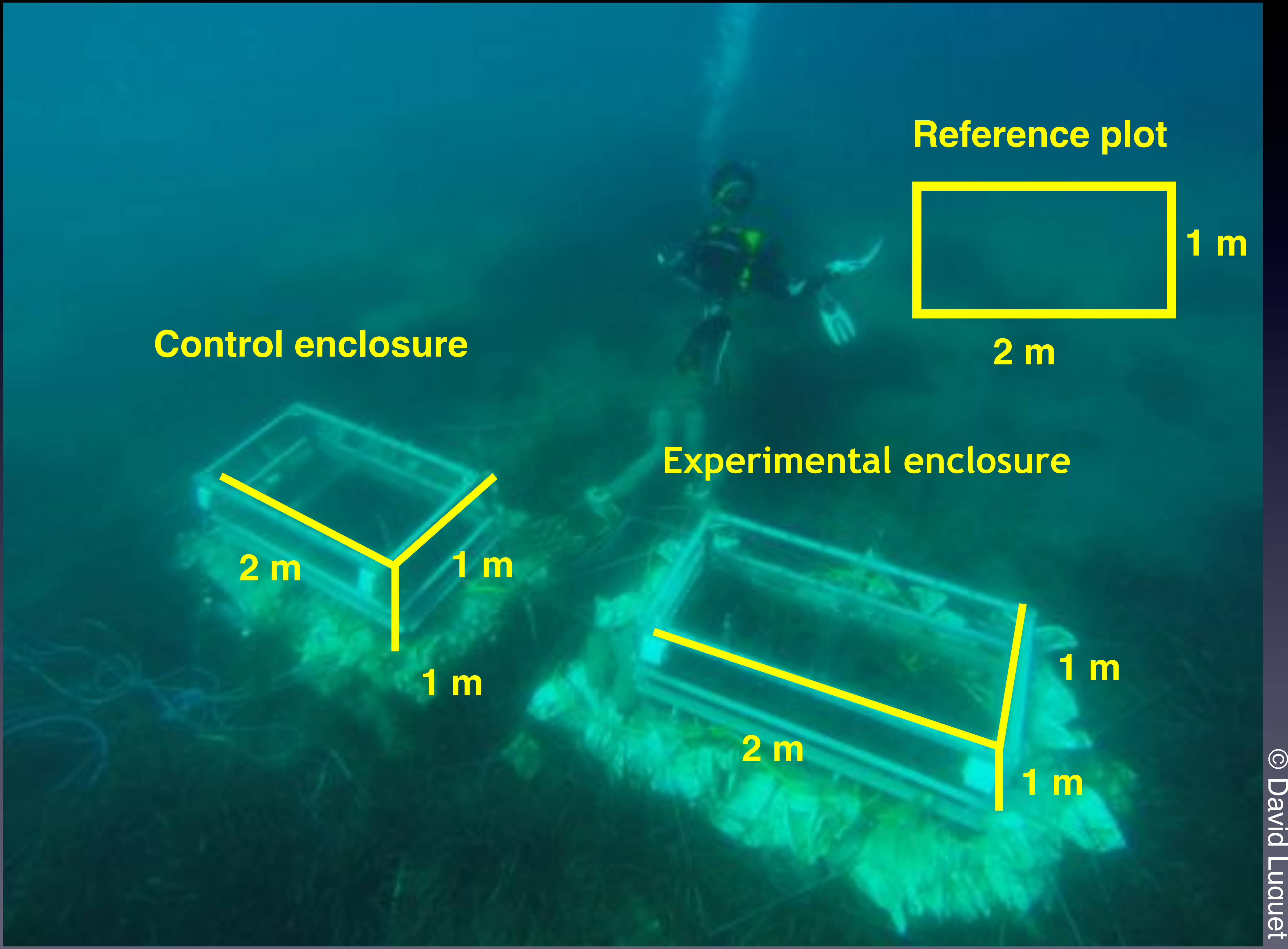


Riebesell & Gattuso (2015)

Benthic mesocosms: eFOCE experiment

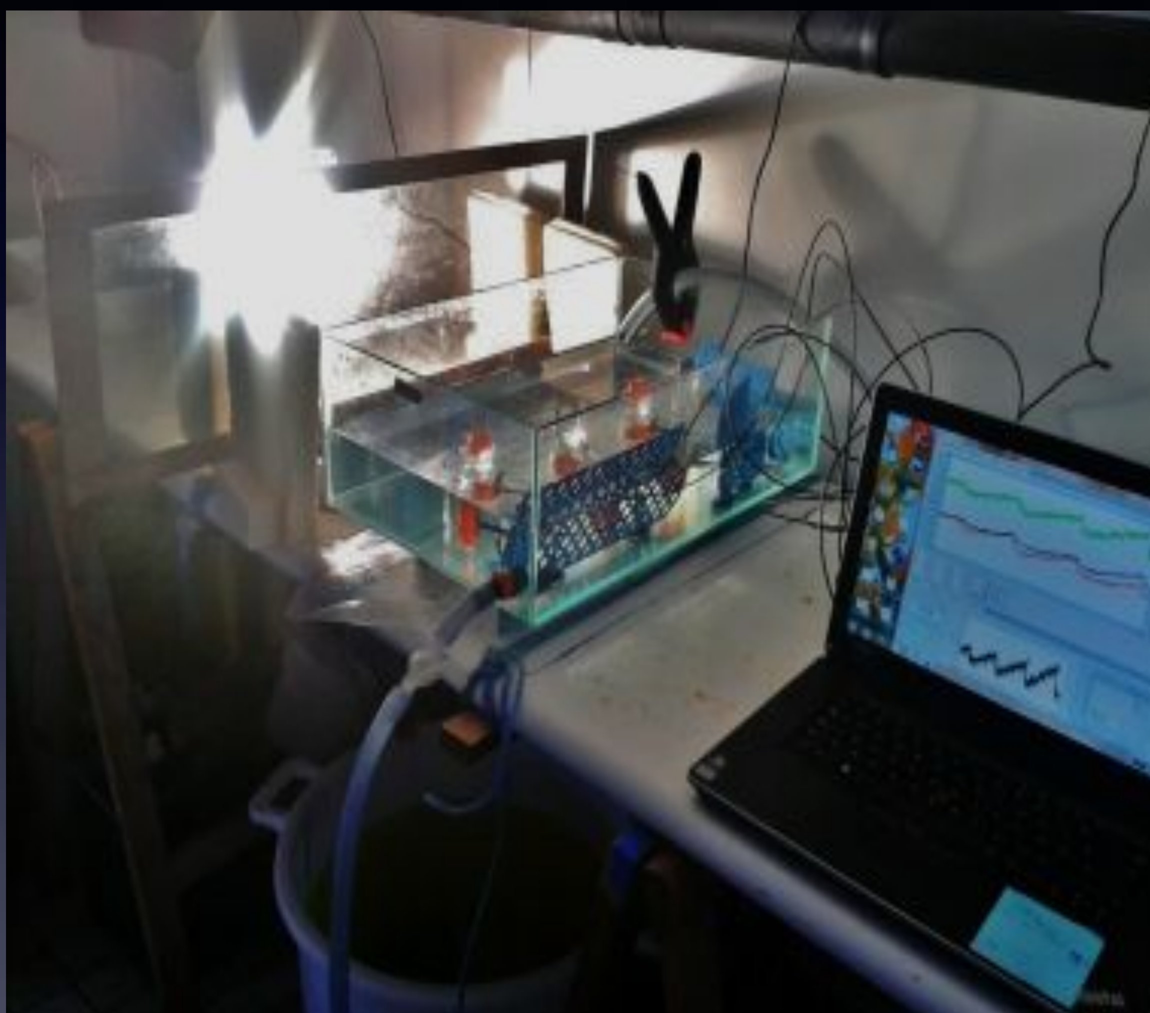


Experimental setup



Photosynthesis

Stimulated in individual leaves

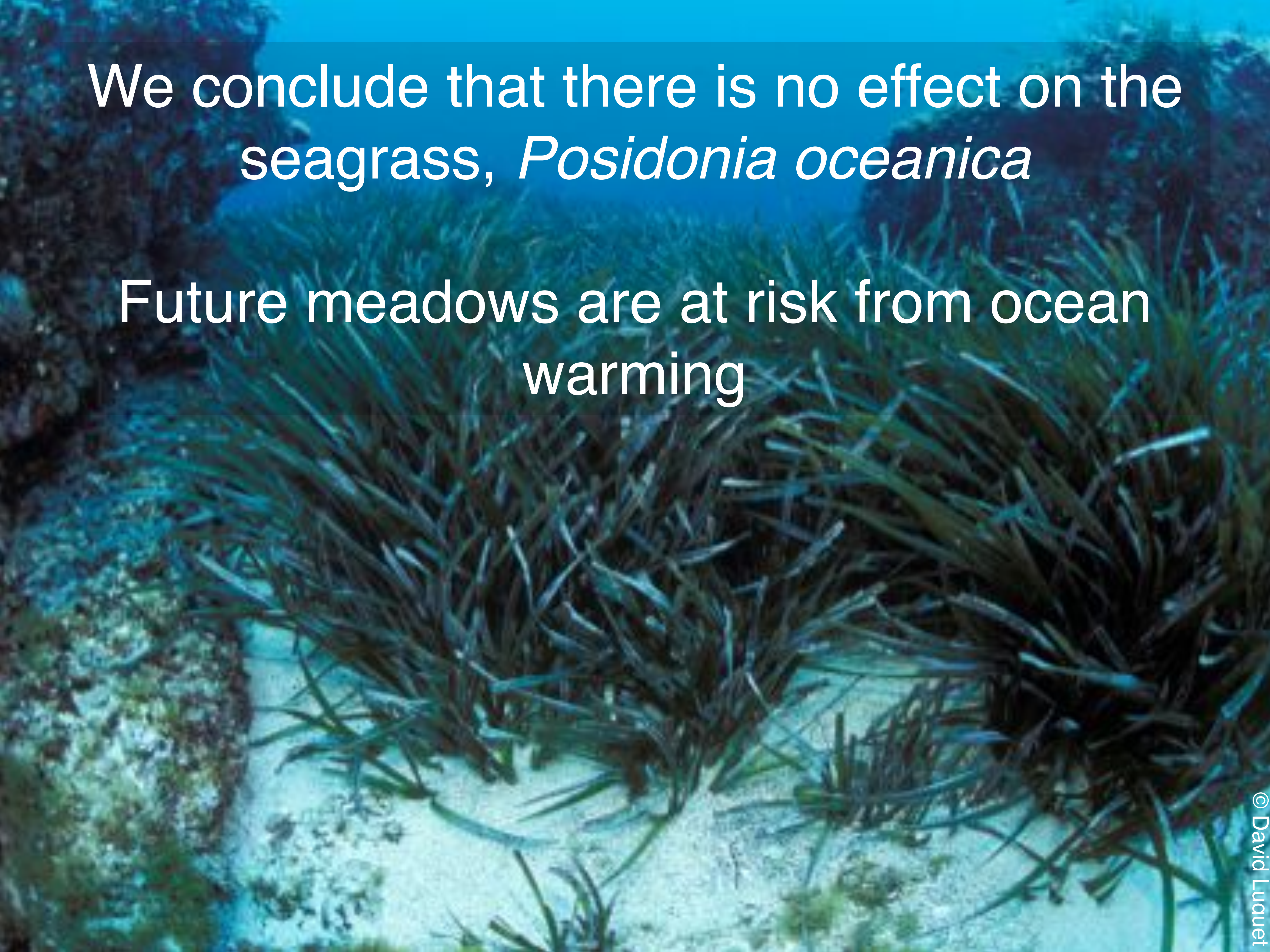


© S. Schenone

No change in the field

© David Luquet

No change in the abundance of organisms

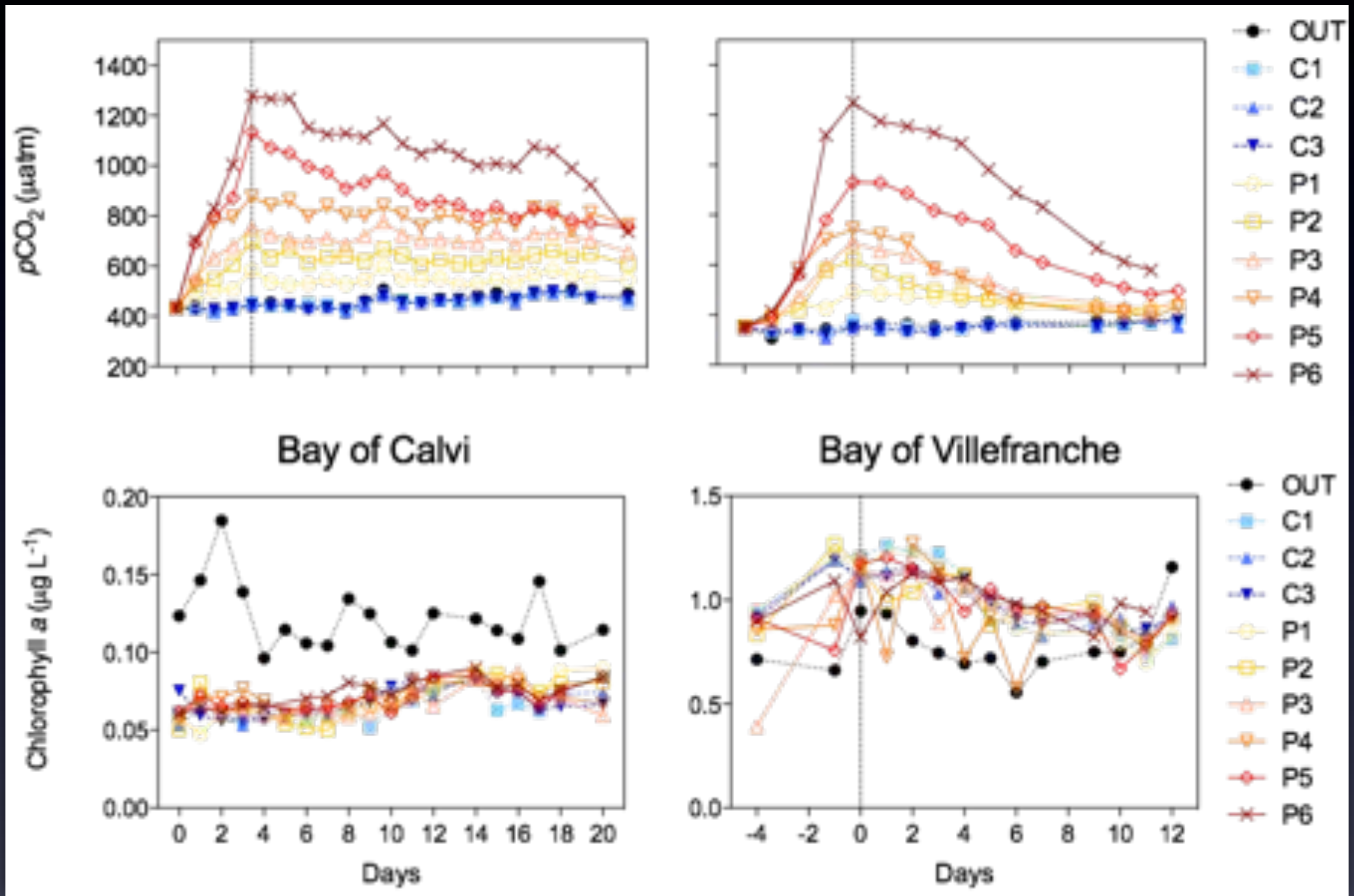

We conclude that there is no effect on the seagrass, *Posidonia oceanica*
Future meadows are at risk from ocean warming
© David Luquet

Pelagic mesocosms

© David Luquet

Slide: courtesy of F. Gazeau

Experimental conditions



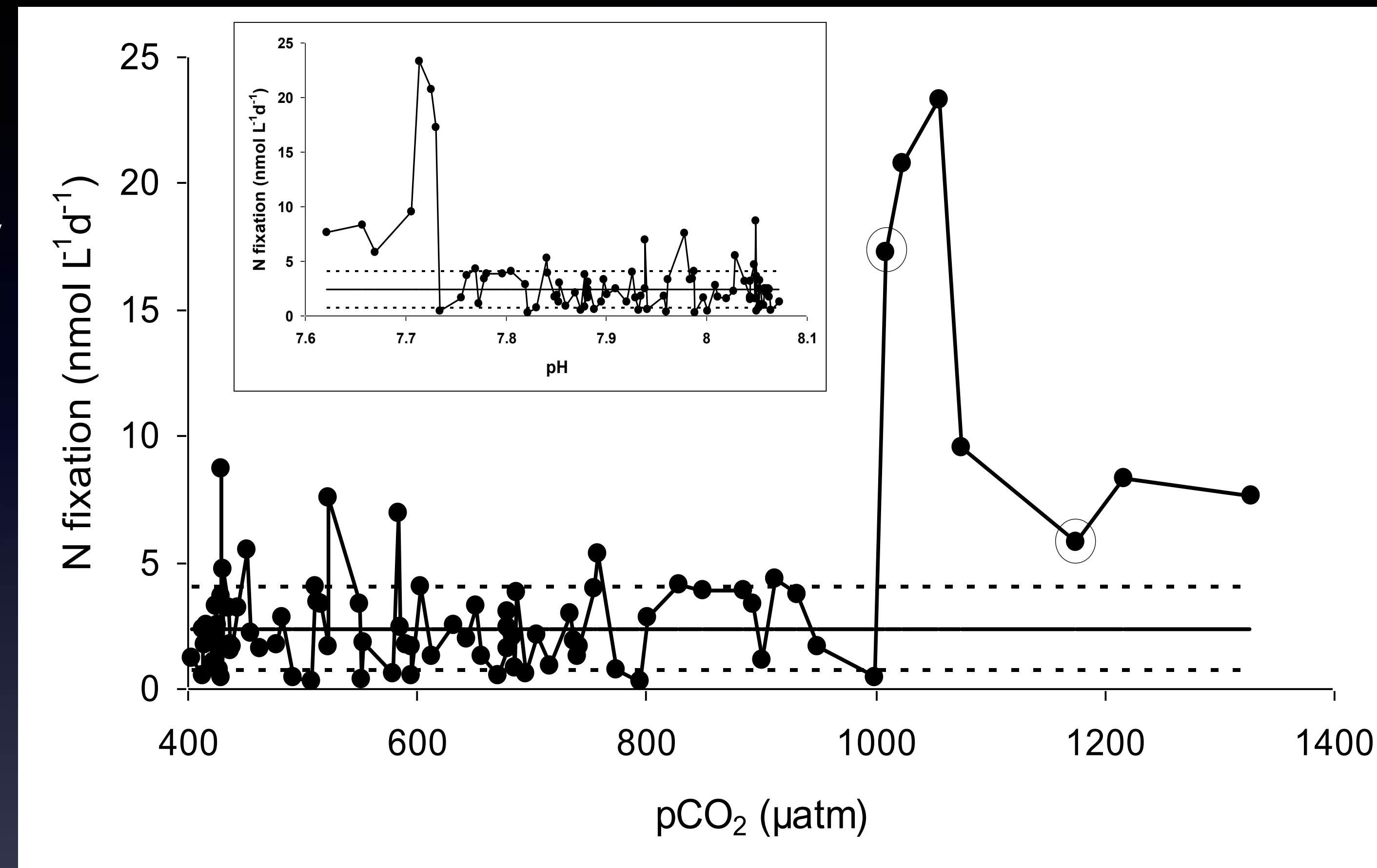
Gazeau et al. (in prep.)

Summer 2012 Winter 2013

Slide: courtesy of F. Gazeau

Key results

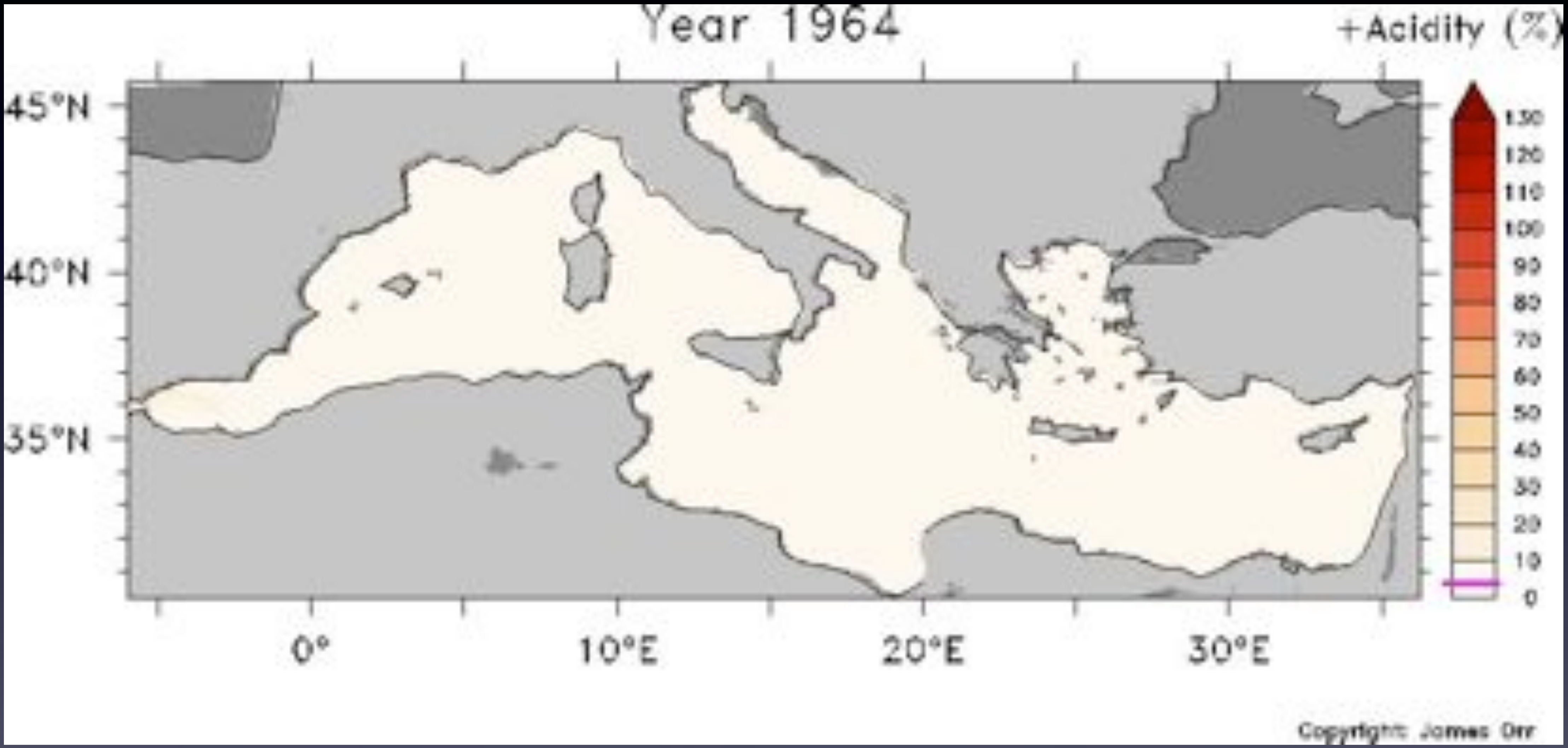
- Very few effects of ocean acidification on these communities which are strongly nutrient-limited
- Nitrogen fixation stimulated in summer above 1000 μatm pCO_2



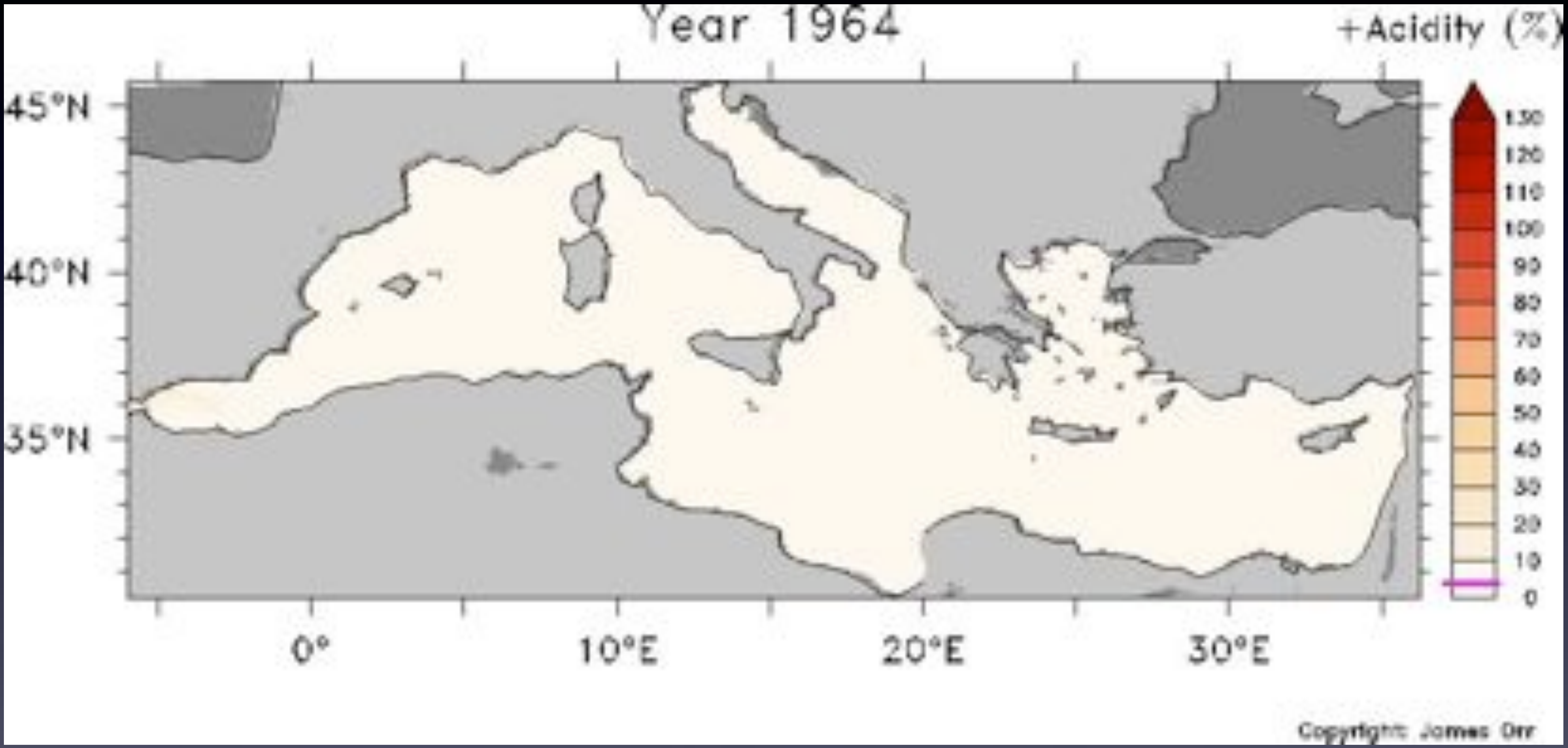
Rees et al. (sbm)

Slide: courtesy of F. Gazeau

Future changes in pH

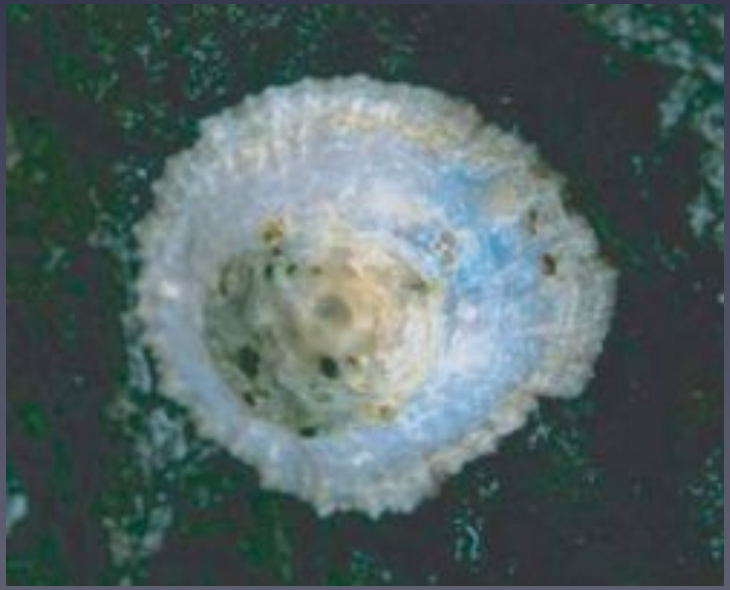


Future changes in pH



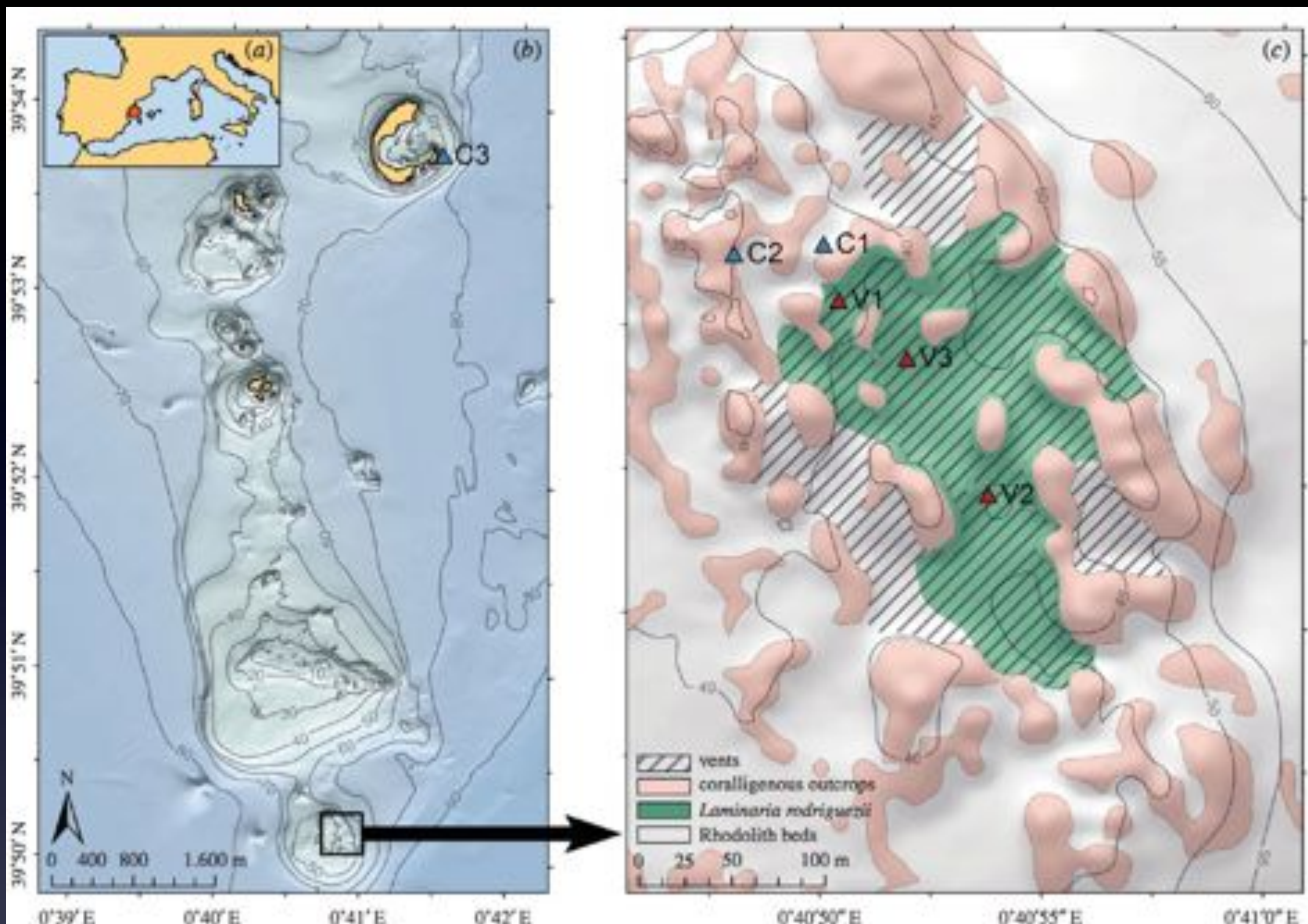
Biodiversity, CO_2 vent, Ischia

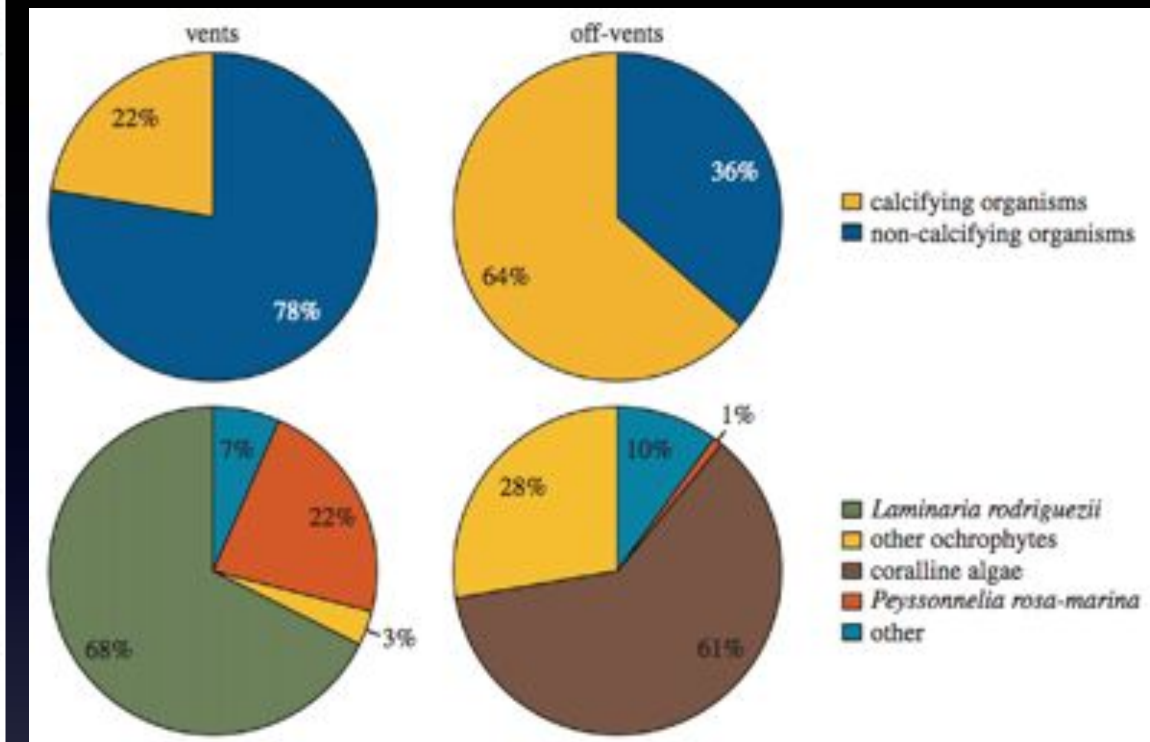
- total loss of some calcareous species
- reduced biodiversity
- altered competitive dynamics between species “regime shifts”: totally different ecosystems
- warming may intensify the effects acidification



Hall-Spencer and colleagues, Plymouth Univ.

CO_2 vent, Spain

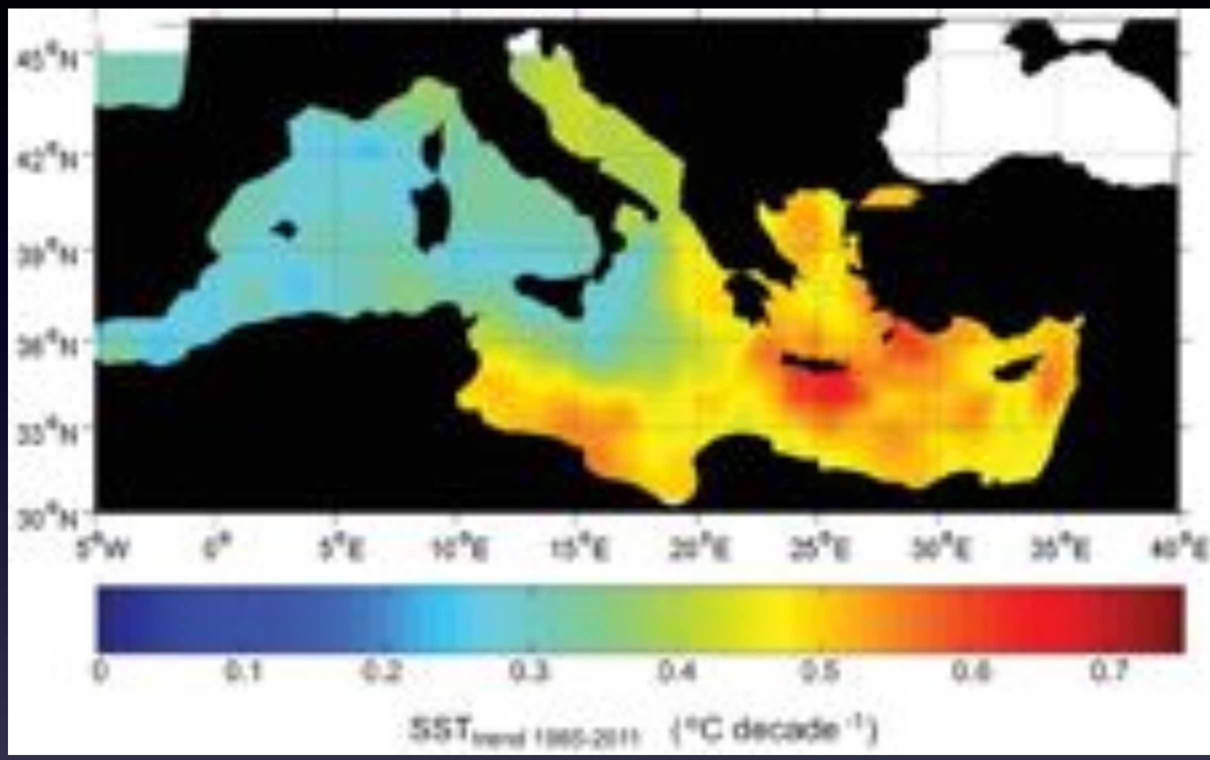




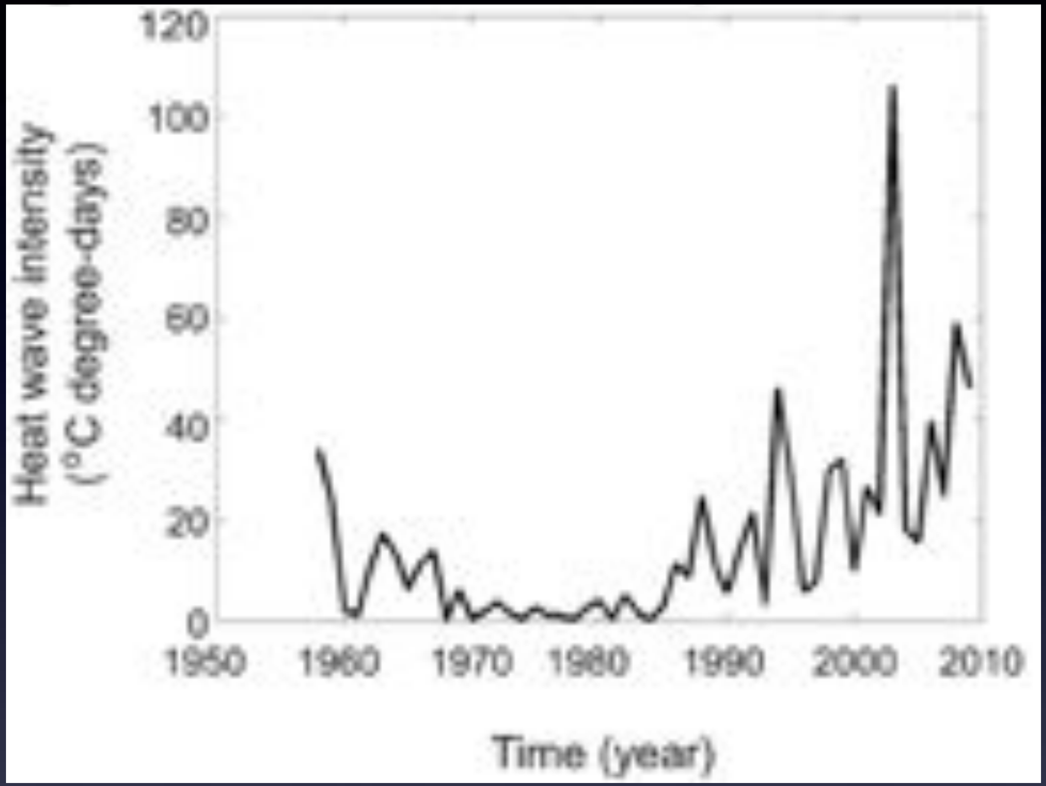
Linares et al. (2015)

Ocean warming

Past warming



Marbá et al. (2015)



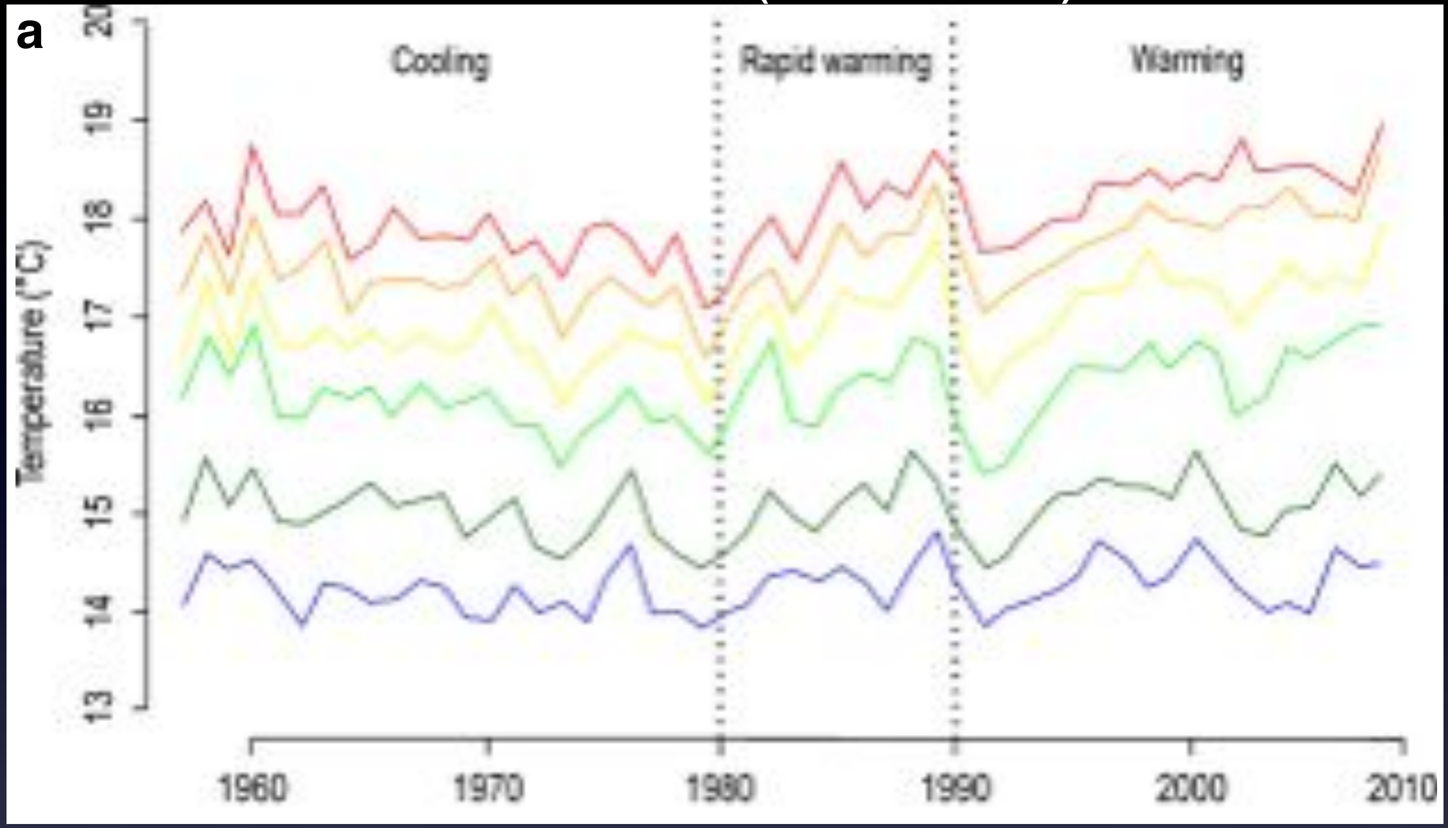
Marbá et al. (2015)

Satellite data (1985-2011):

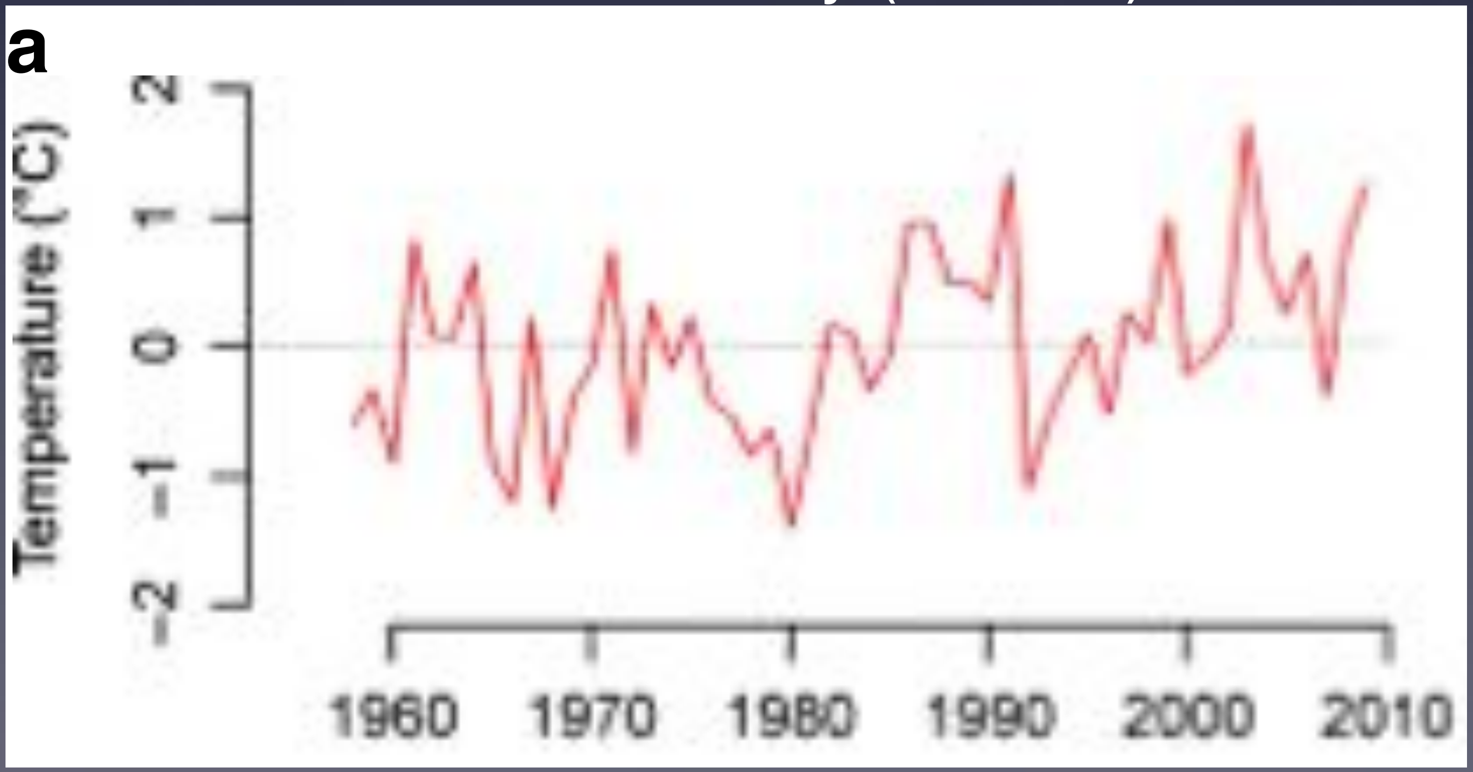
- Summer SST: +1.15°C
- +0.25°C decade^{-1} in the western basin
- +0.65°C decade^{-1} in the eastern basin

Temperature, Bay of Villefranche

Annual mean (0 to 75 m)

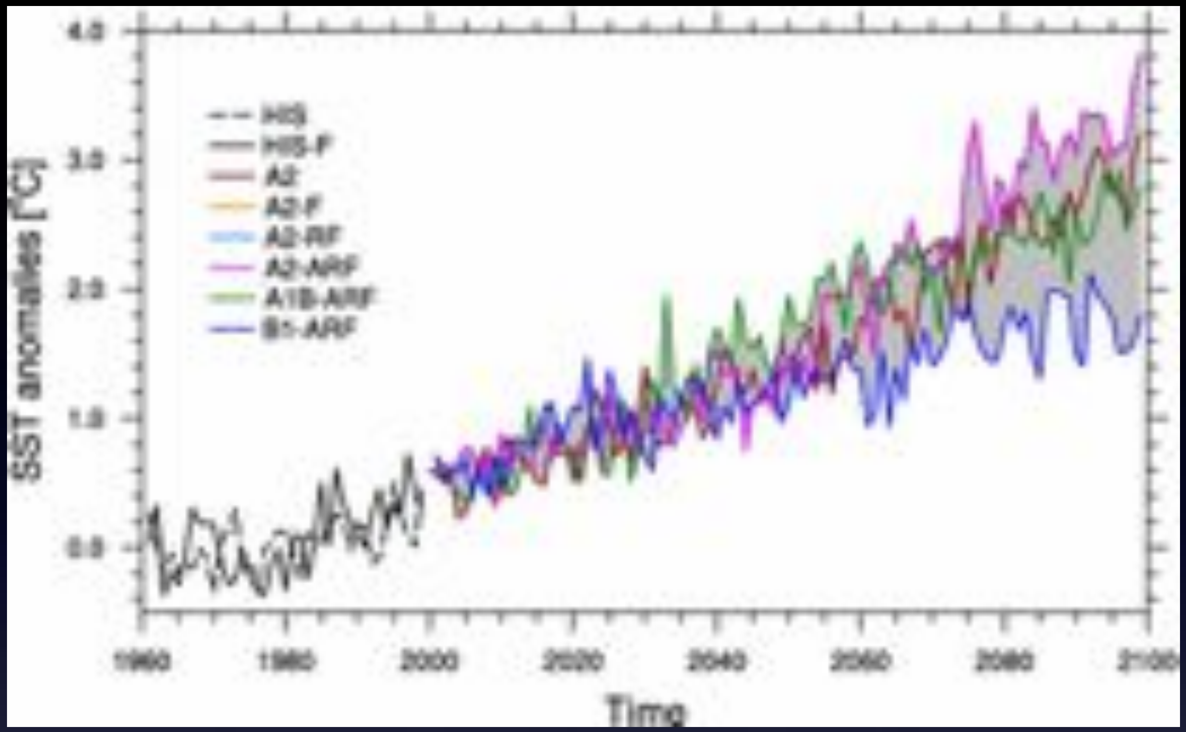


Summer anomaly (surface)

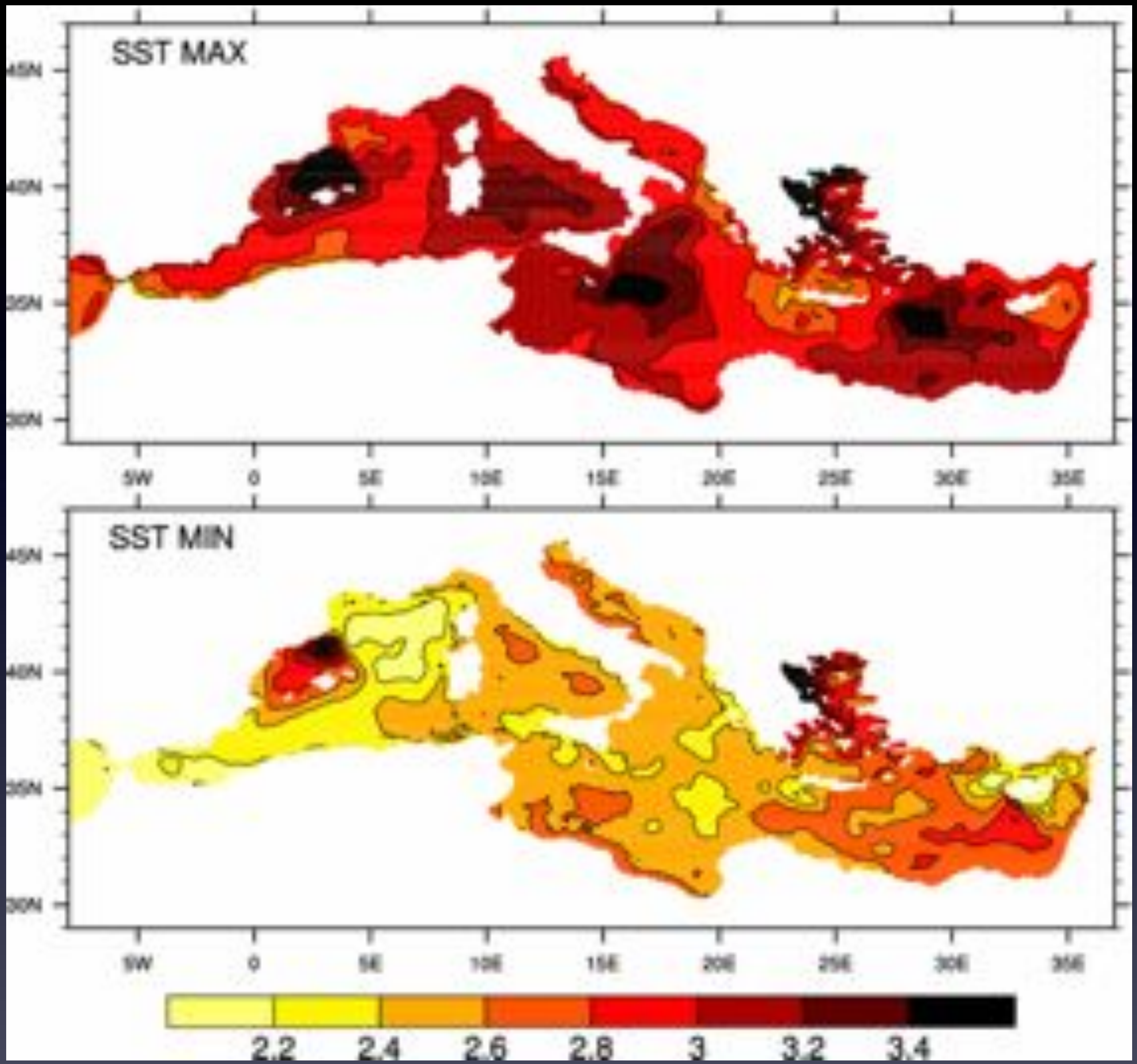


Parravicini et al. (2015)

Future warming



Adloff et al. (2015)



Adloff et al. (2015)

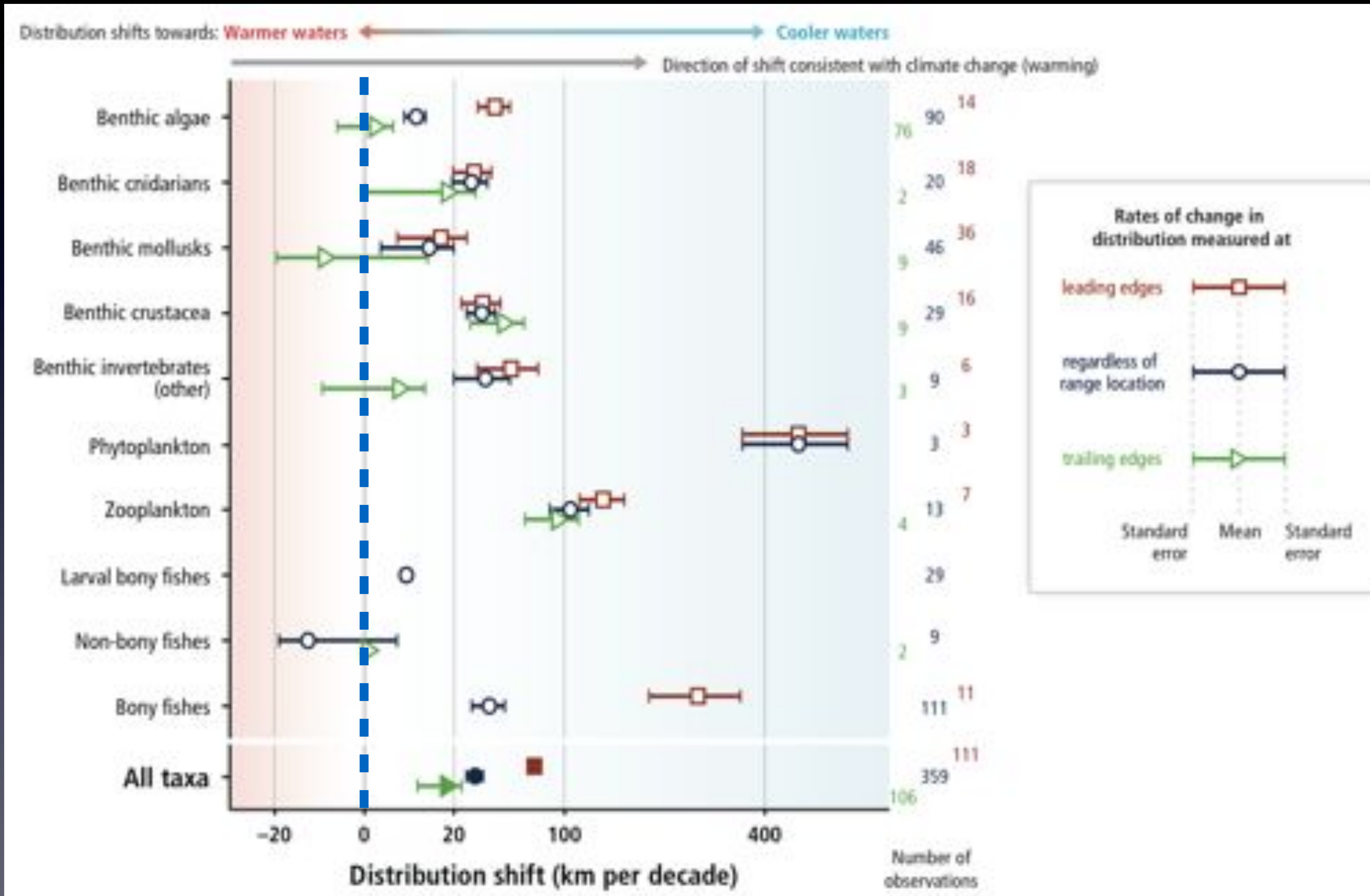
Composite of SST anomalies 2070- 2099 vs. 1961–1990 (largest and smallest anomaly out of the 6 scenario simulations at each grid point)

Warming: mass mortalities

Gattuso et al. (2014). © R. Berkelmans

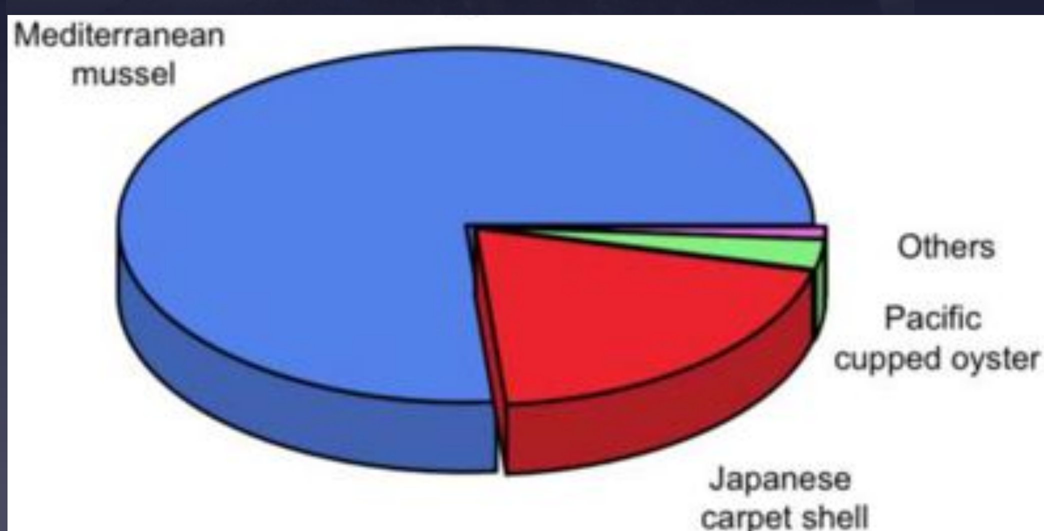
Also in the Mediterranean Sea

Warming: redistribution of species

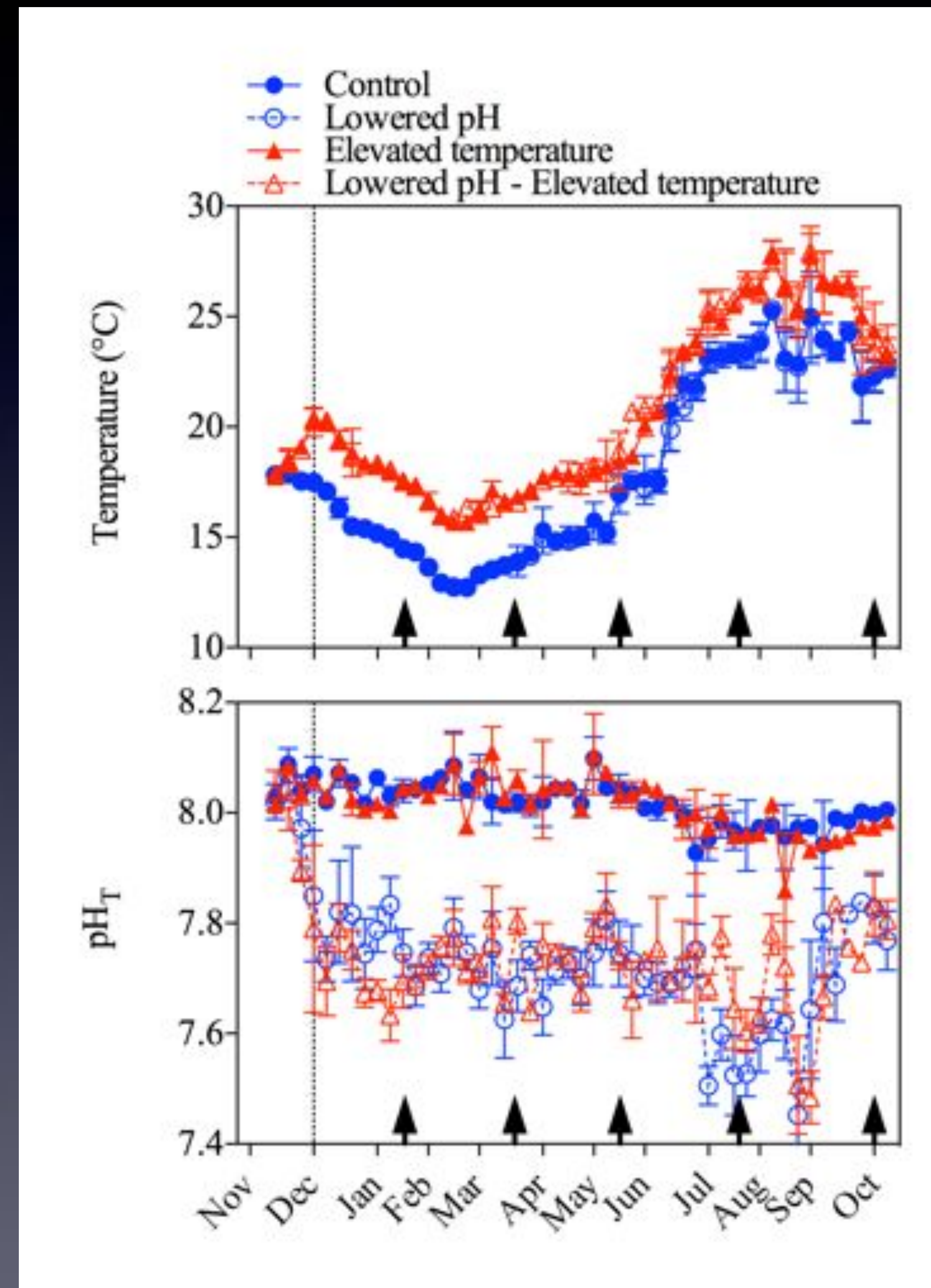


Poloczanska et al. (2014)

Commercial species



> 75 % of bivalve production in the Mediterranean
(Lacoue-Labarthe et al., in press)



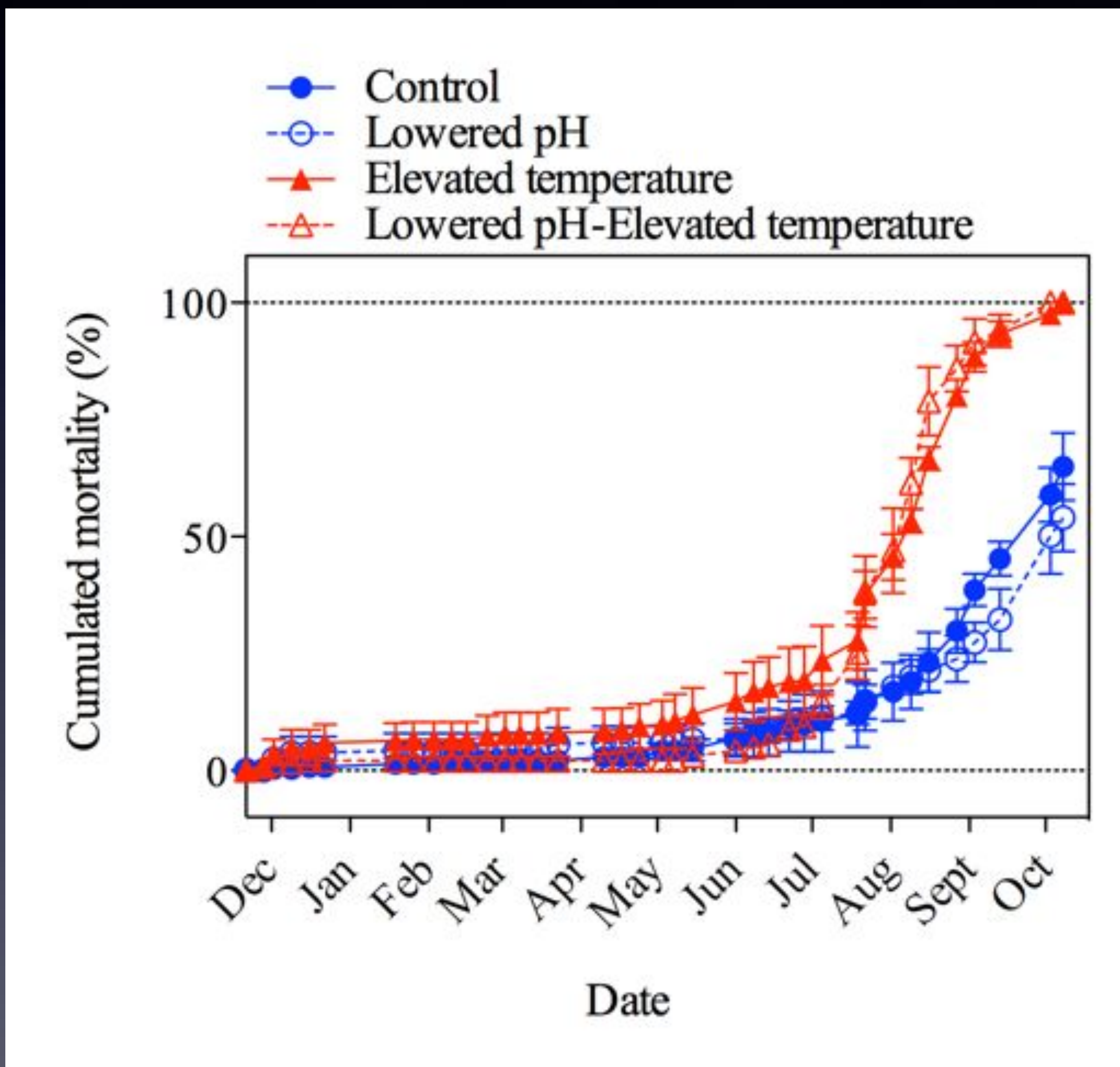
Gazeau et al. (2014)

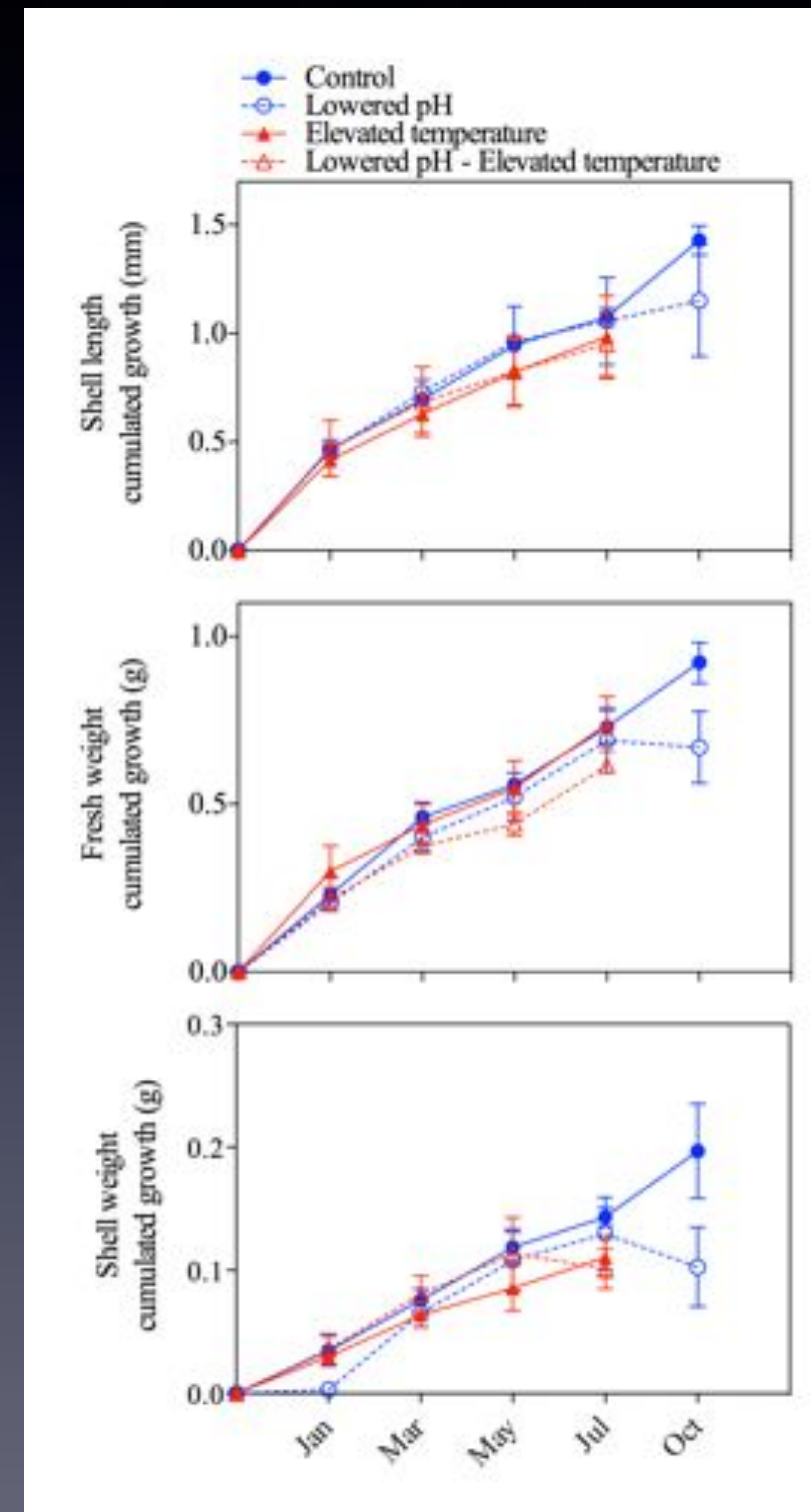
Slide: courtesy of F. Gazeau

Response of a Mediterranean mussel

No effect of ocean acidification on growth

Excess mortality due to warming



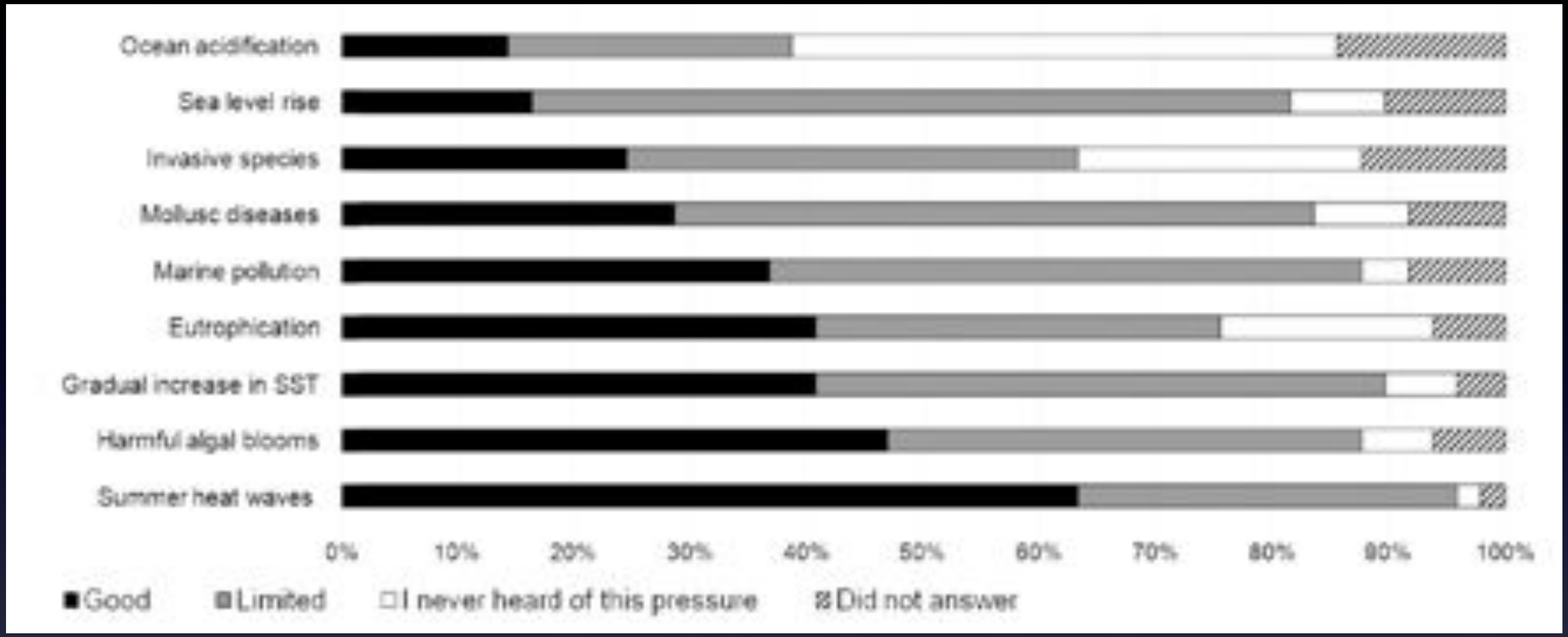


Gazeau et al. (2014)

Slide: courtesy of F. Gazeau

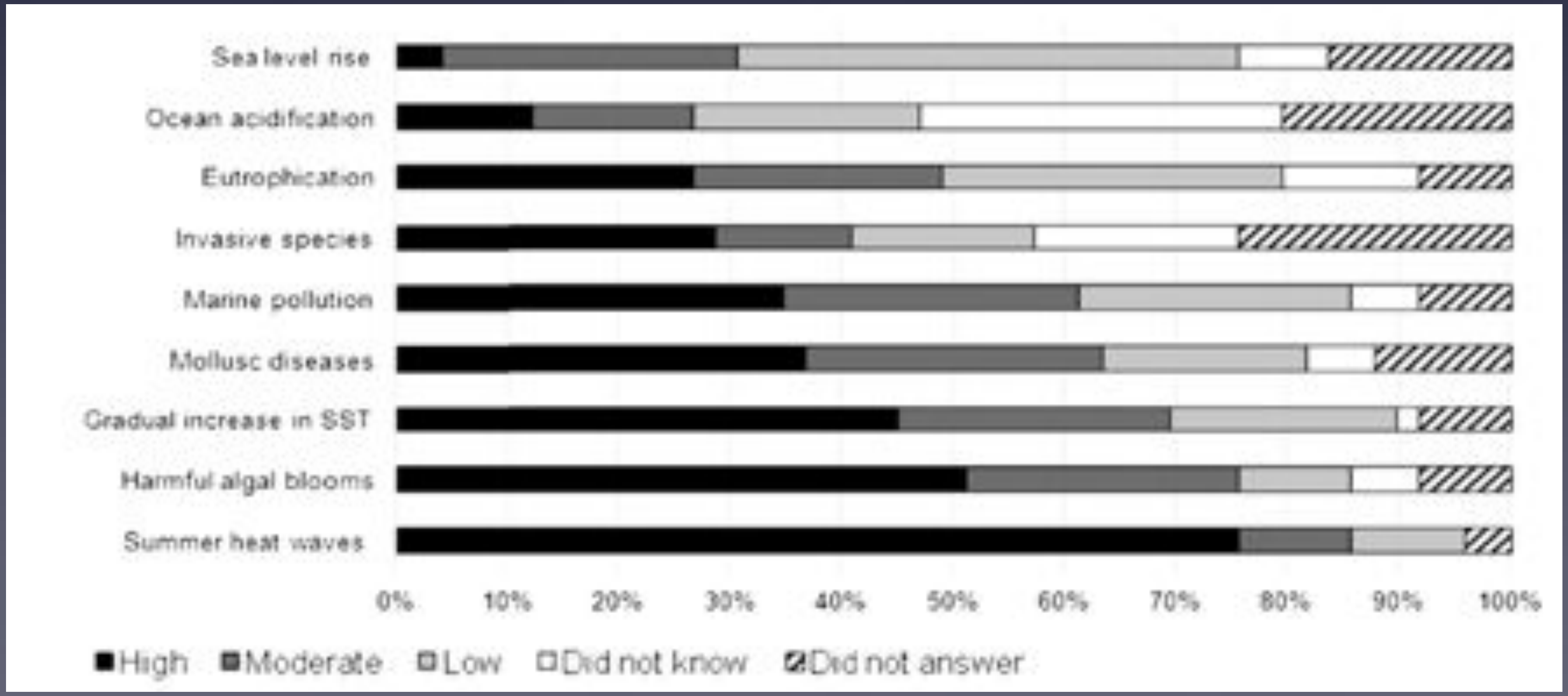
Survey of Mediterranean mussel producers

Level of knowledge



Rodrigues et al. (in press)

Perception of level of threat



Rodrigues et al. (in press)

Key ecosystems, species and impacts

Ecosystem	*Key species*	Response to OA	Response to warming	Combined effect
Seagrass meadows	*P. oceanica*	Increased productivity	deterioration	
Coralligenous reefs	*L. lichnoides, coral species*	Crustose Coralline Algae (CCA) cease	CCA and coral mortality	
Vermetid reefs	*V. triqueter, D. petraeum, N. brassica-florida*	Slower calcification, recruitment	Mortality	Greater mortality
Mussel beds	*M. galloprovincialis*	No response unless in high temp	Larval mortality	Greater mortality at low pH with increased temp





Global impacts of ocean acidification and warming

REVIEW

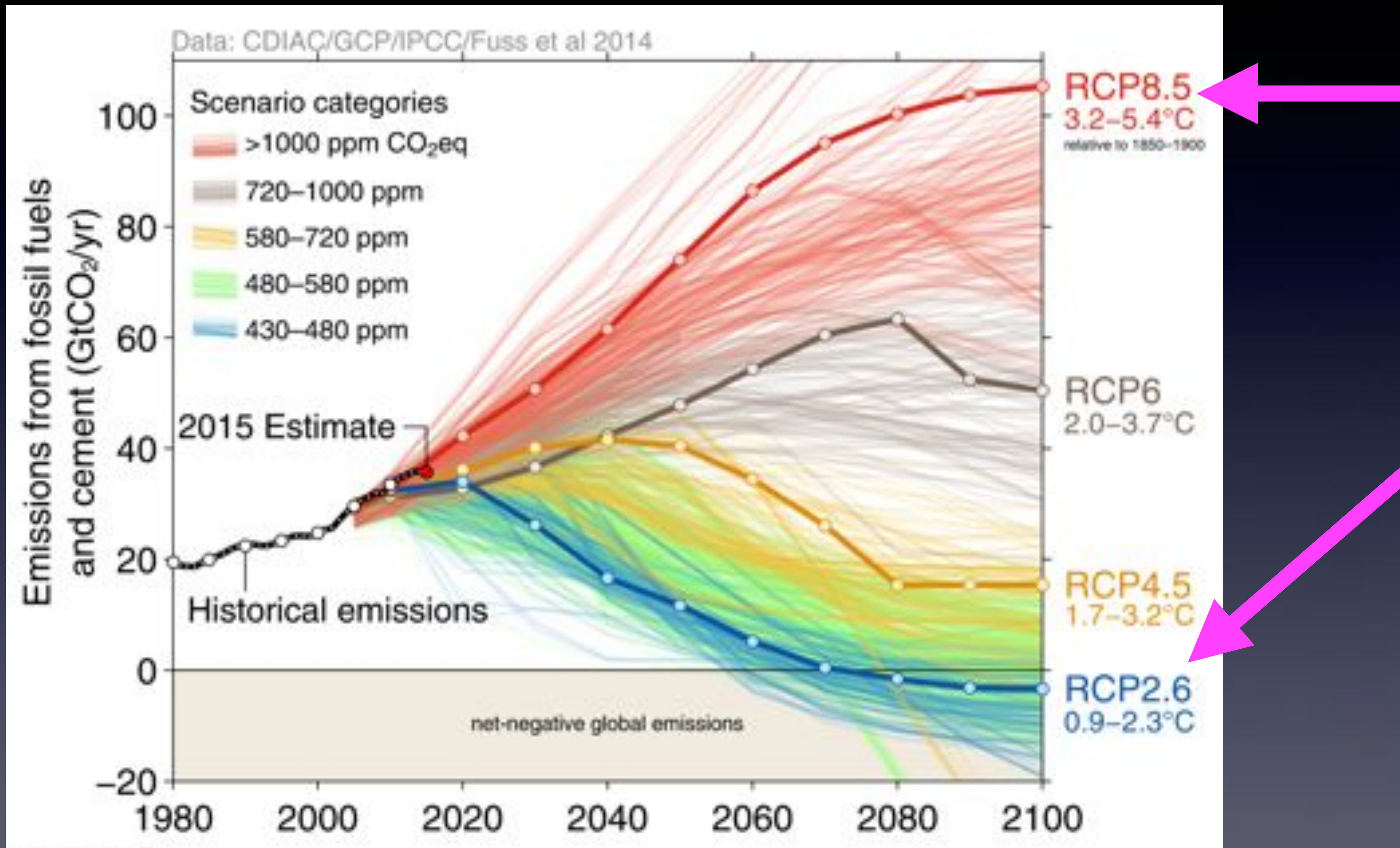
OCEANOGRAPHY

Contrasting futures for ocean and society from different anthropogenic CO_2 emissions scenarios

J.-P. Gattuso,[1,2,3*] A. Magnan,[3] R. Billé,[4] W. W. L. Cheung,[5] E. L. Howes,[6] F. Joos,[7] D. Allemand,[8,9] L. Bopp,[10] S. R. Cooley,[11] C. M. Eakin,[12] O. Hoegh-Guldberg,[13] R. P. Kelly,[14] H.-O. Pörtner,[6] A. D. Rogers,[15] J. M. Baxter,[16] D. Laffoley,[17] D. Osborn,[18] A. Rankovic,[3,19] J. Rochette,[3] U. R. Sumaila,[20] S. Treyer,[3] C. Turley[21]

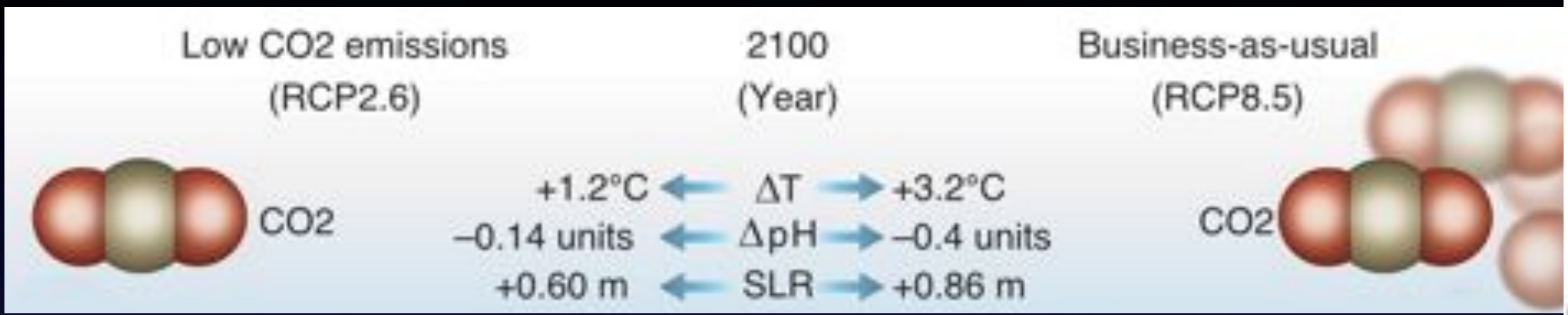
Science, July 2015

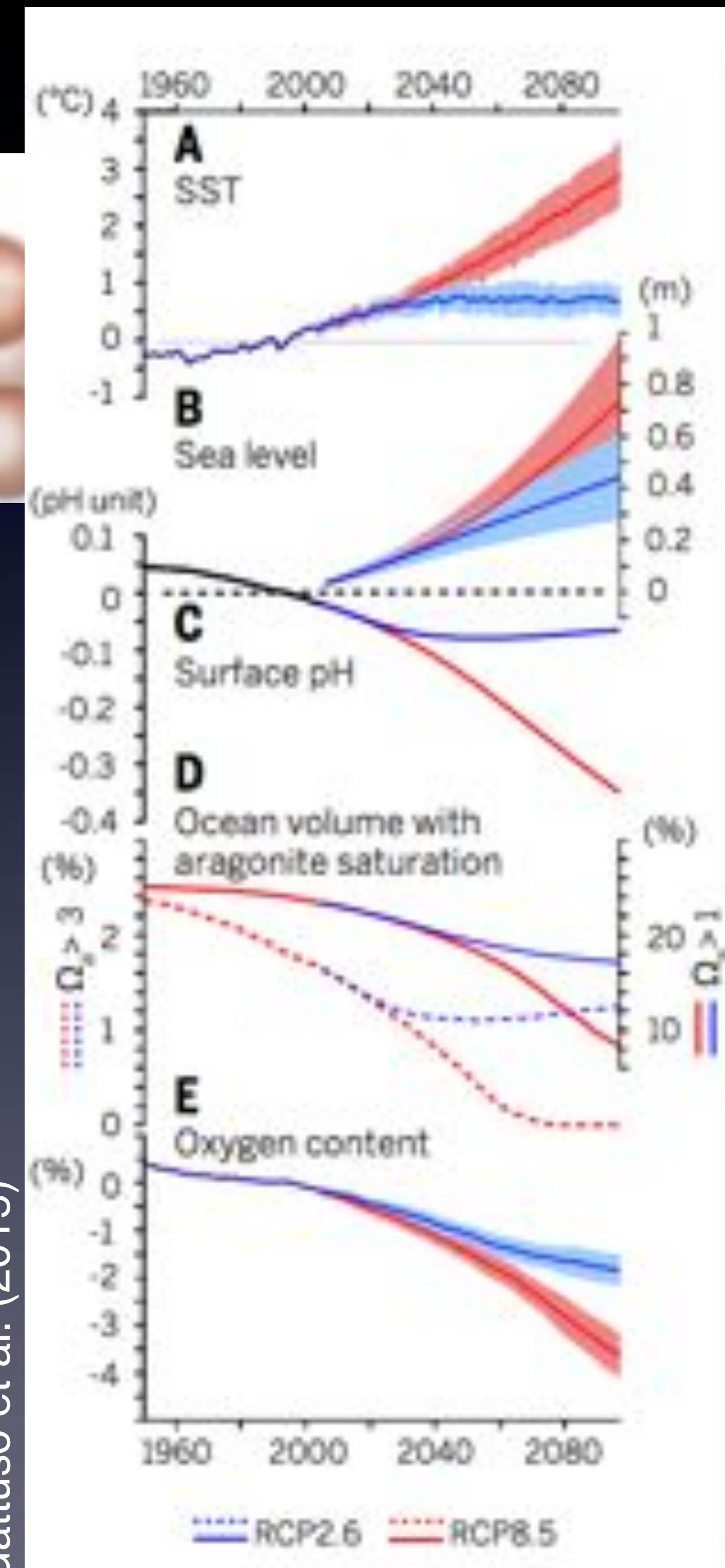
Future scenarios



Physics and chemistry

Two scenarios considered





Gattuso et al. (2015)

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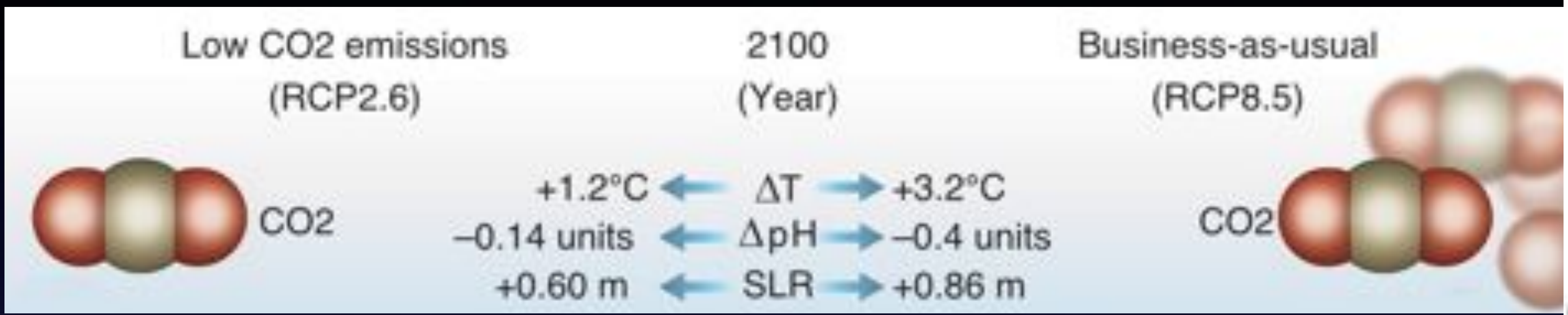
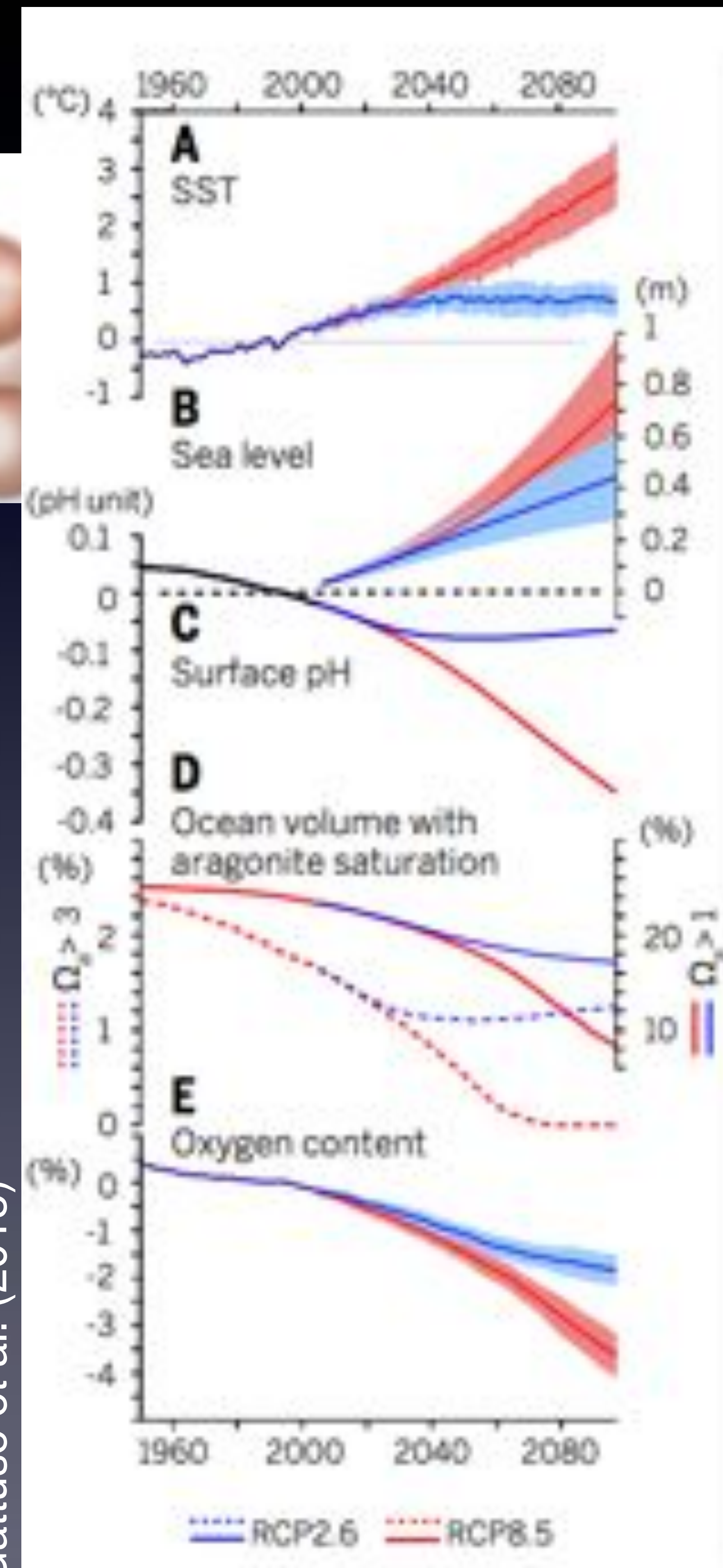


Significant gaps:

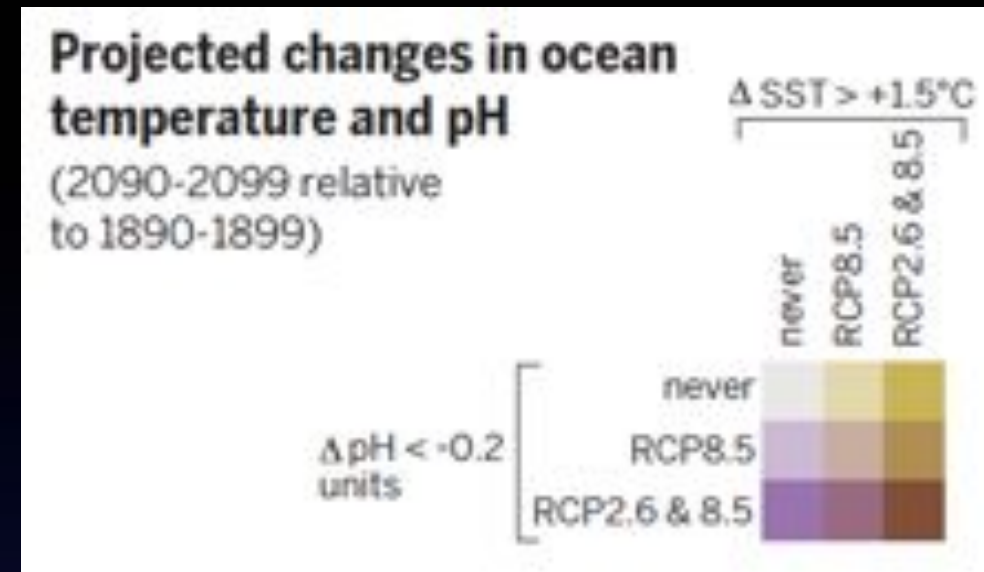
- Regional projections, e.g. sea level and low oxygen areas
- Projections in the coastal zone
- Changes in the internal and decadal variability

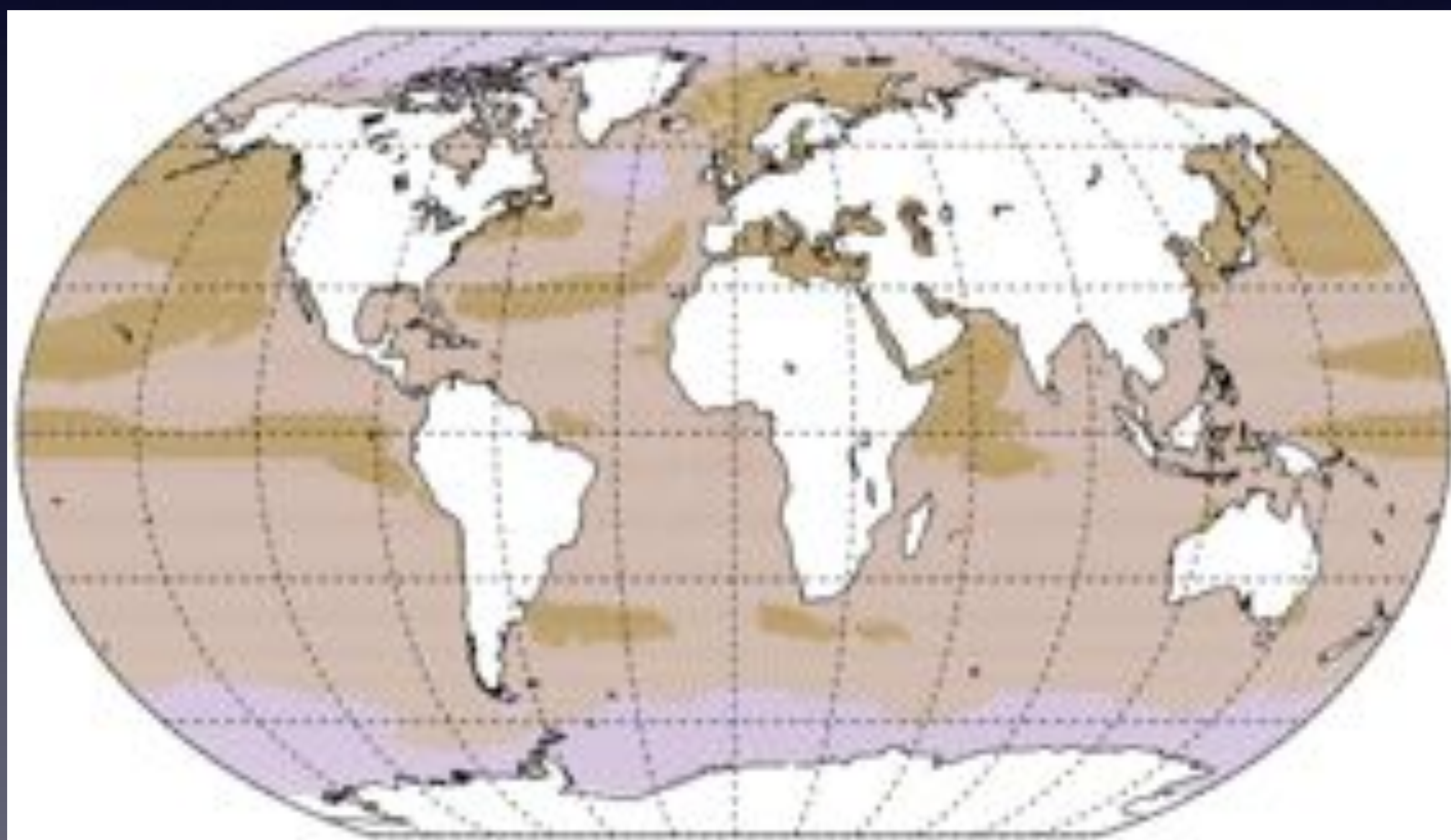


Gattuso et al. (2015)

Projections for 2100

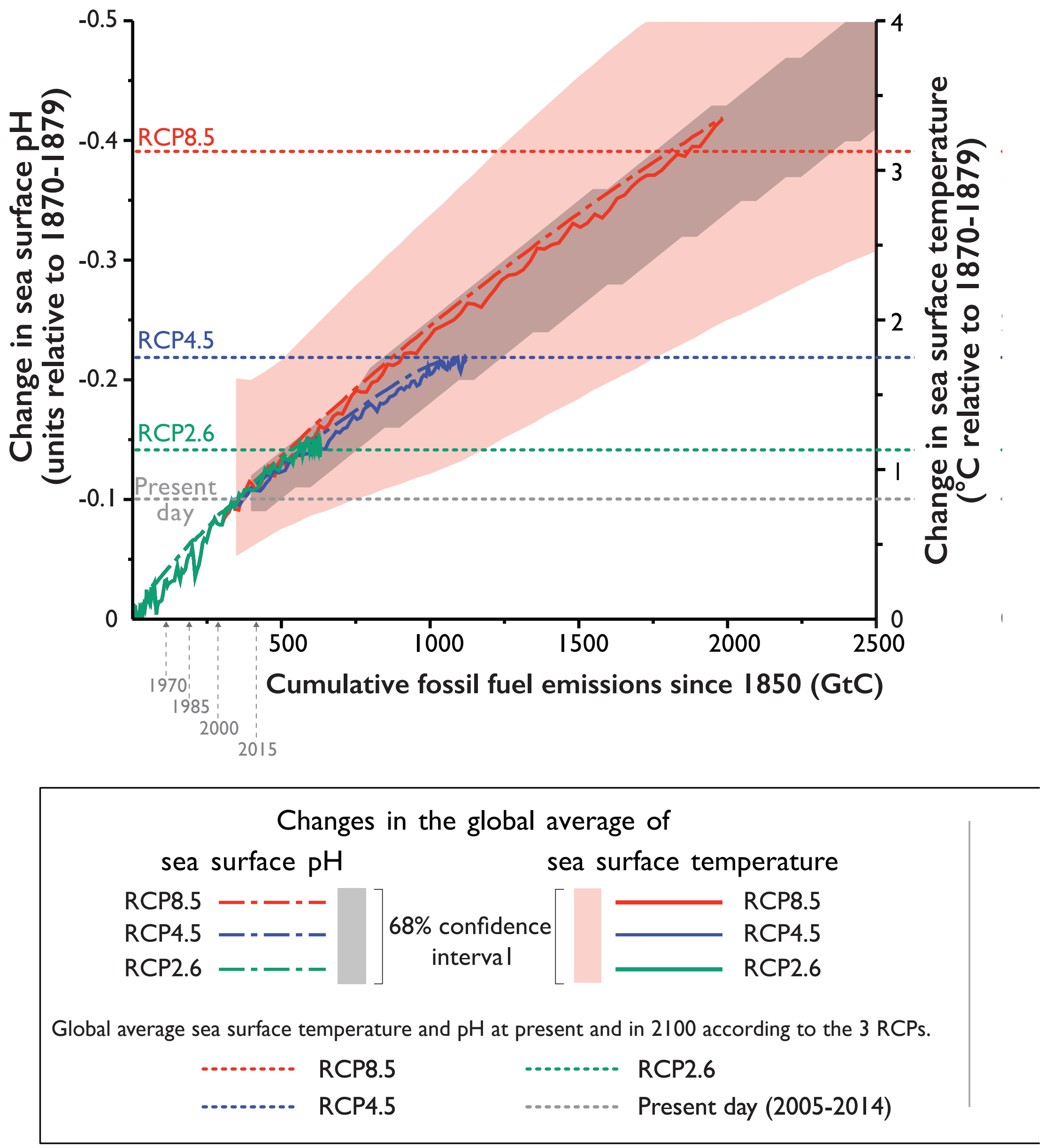
- Thresholds: +1.5 °C and -0.2 pH units relative to preindustrial
- RCP8.5: **69%** of the ocean surface will exceed both thresholds
- RCP2.6: < **1%**





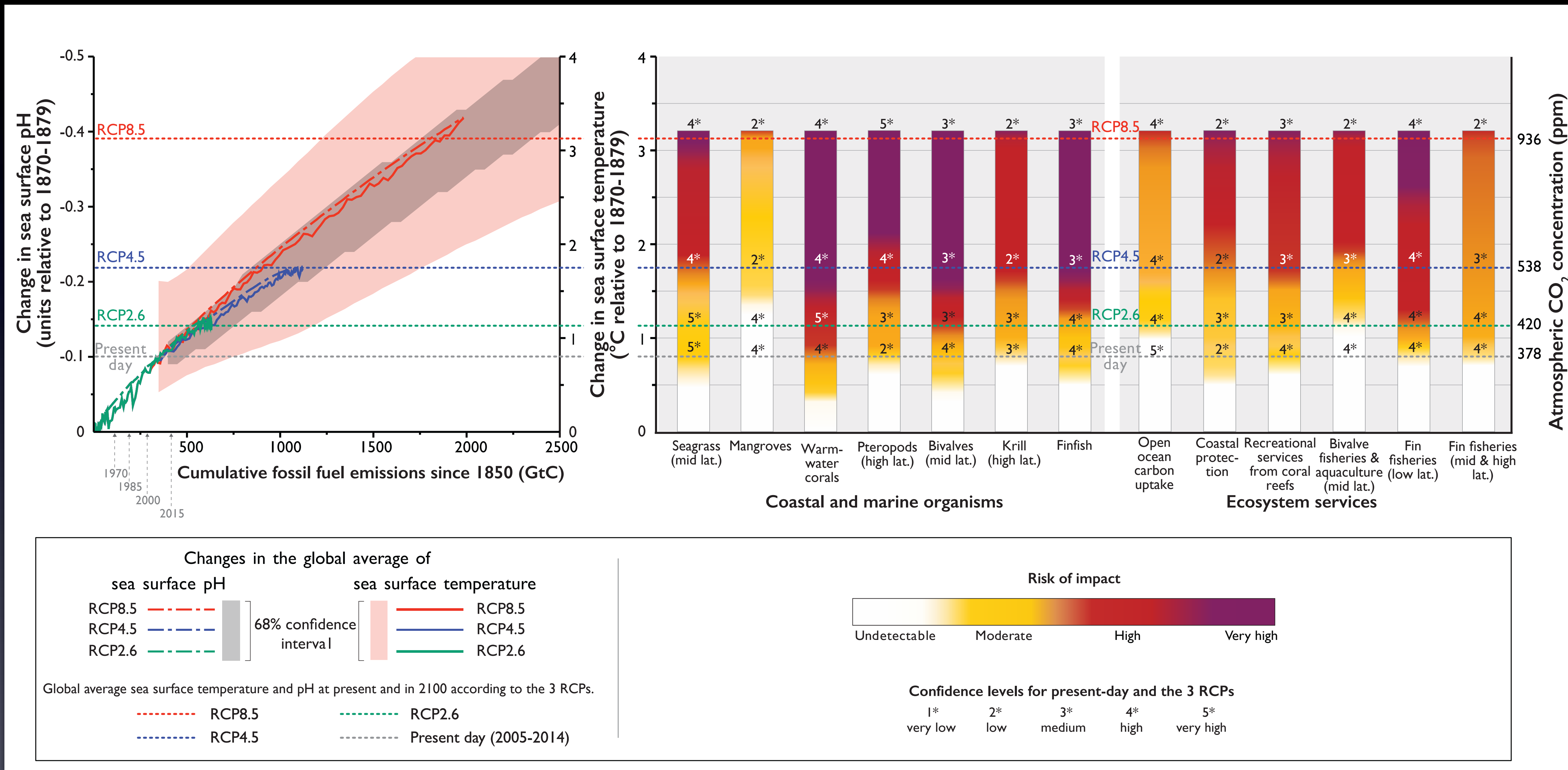
Gattuso et al. (2015)

Risks of impact on marine and coastal organisms and ecosystem services

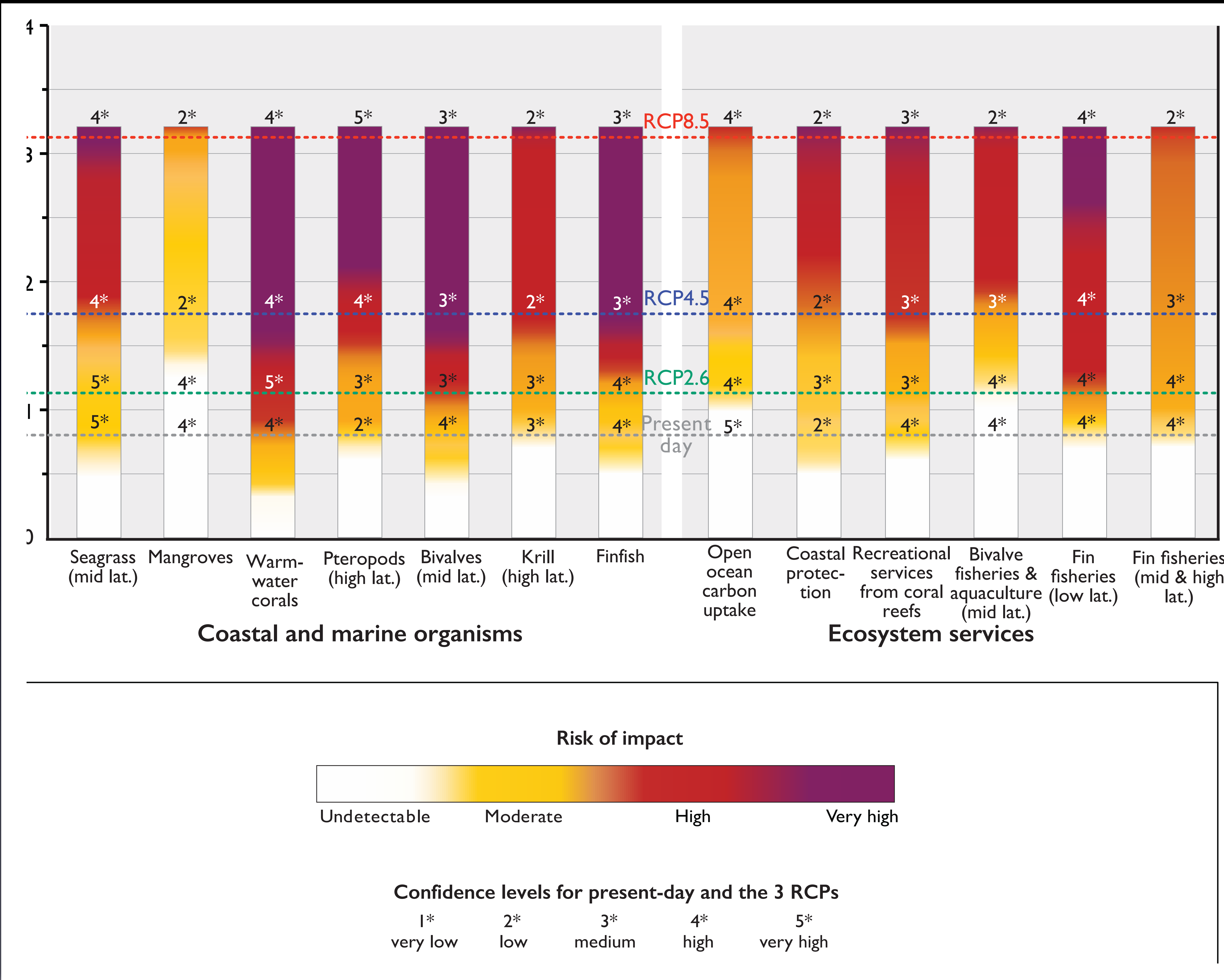


Gattuso et al. (2015)

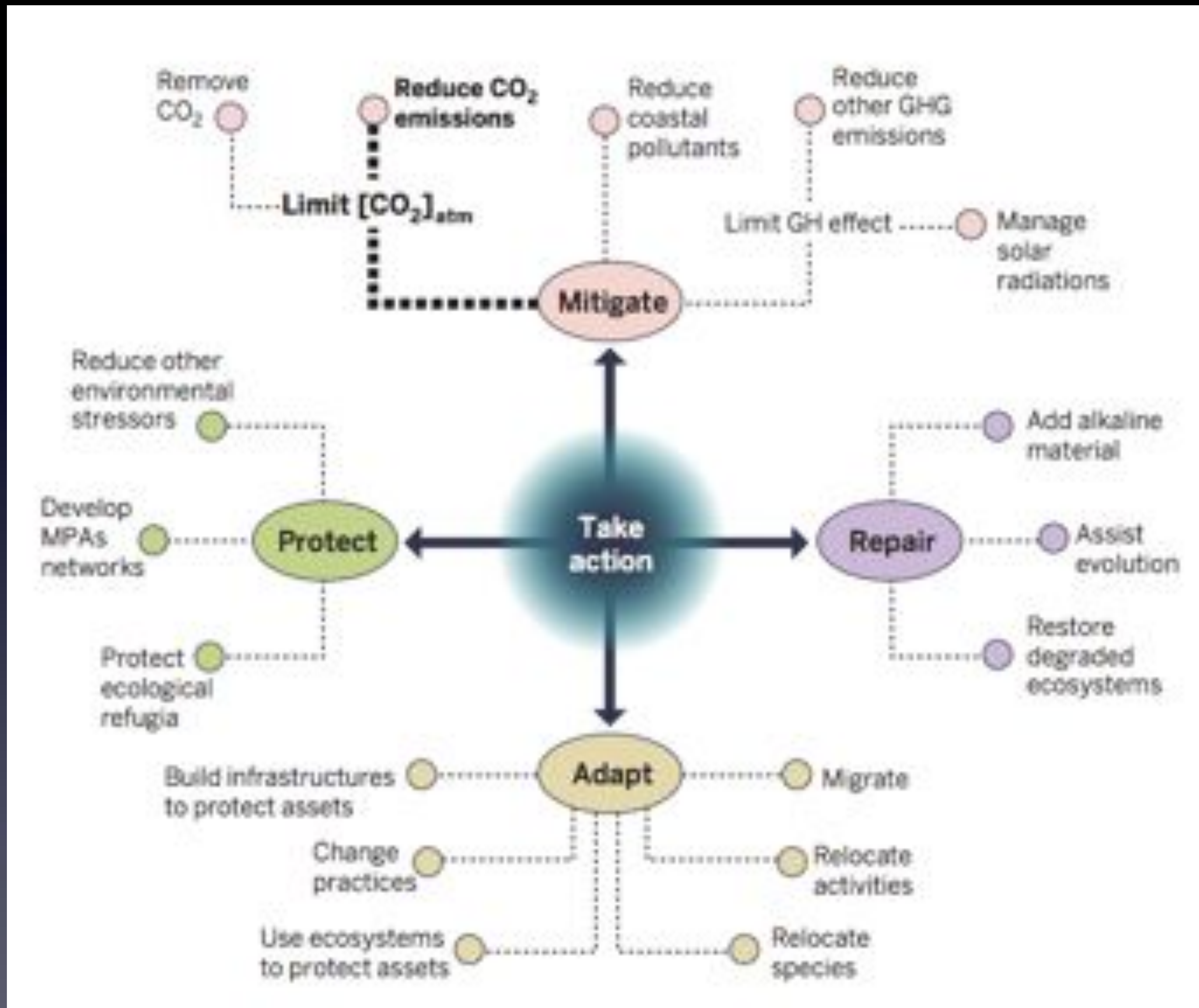
Risks of impact on marine and coastal organisms and ecosystem services



Gattuso et al. (2015)

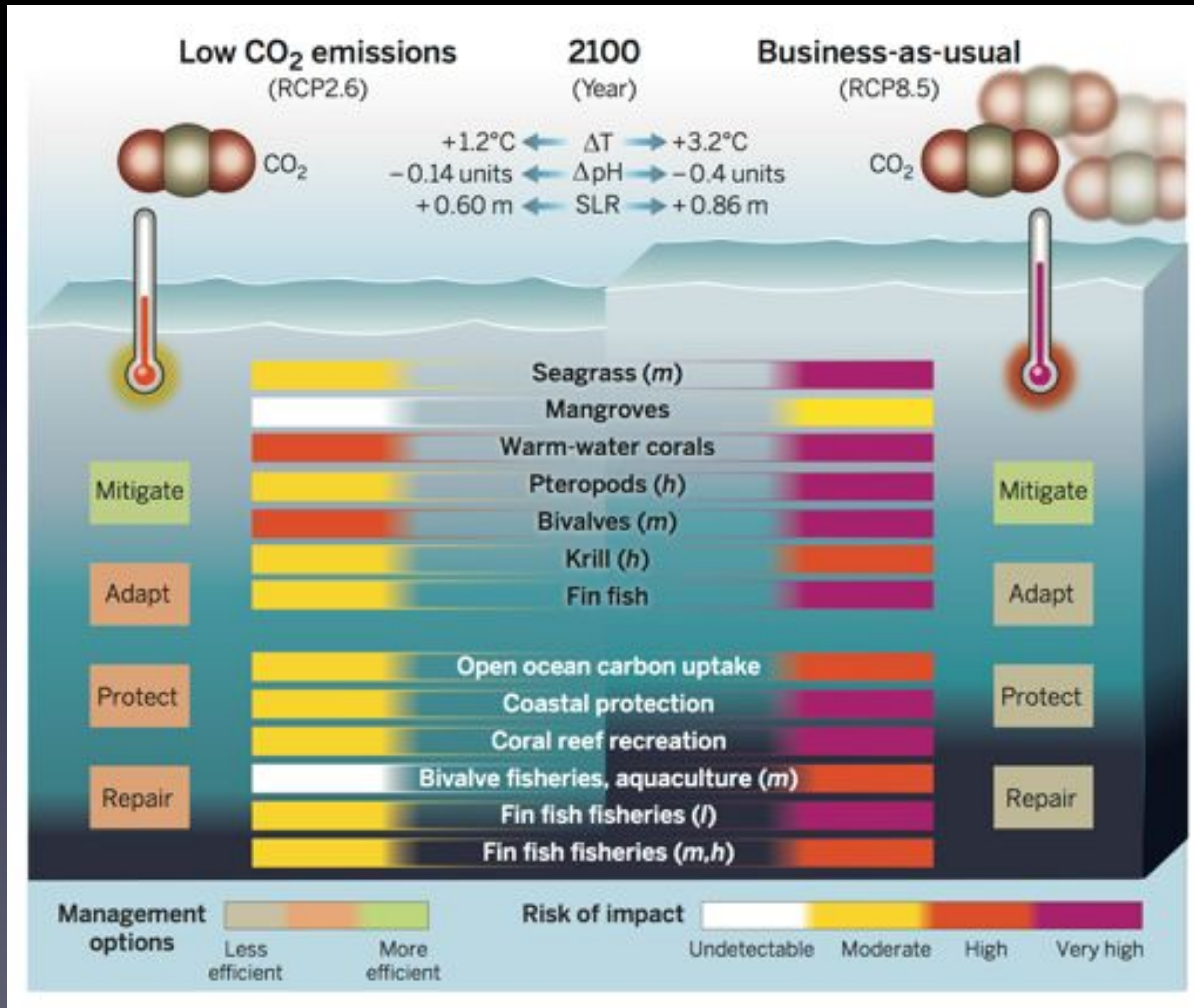

RCP8.5
RCP4.5
RCP2.6
Present day
Seagrass (mid lat.)
Mangroves
Warm-water corals
Pteropods (high lat.)
Bivalves (mid lat.)
Krill (high lat.)
Finfish
Open ocean carbon uptake
Coastal protection
Recreational services from coral reefs
Bivalve fisheries & aquaculture (mid lat.)
Fin fisheries (low lat.)
Fin fisheries (mid & high lat.)
Coastal and marine organisms
Ecosystem services
Risk of impact
Undetectable
Moderate
High
Very high
Confidence levels for present-day and the 3 RCPs
1* very low
2* low
3* medium
4* high
5* very high

Solutions



Gattuso et al. (2015)

Summary



Gattuso et al. (2015)

4 key messages

1. Ocean strongly influences the climate system and important provider of key services
2. Impacts already detectable, high risk of impacts well before 2100, even with a low emission scenario
3. Immediate and substantial reduction of CO_2 emissions to prevent massive and mostly irreversible impacts
4. As CO_2 increases, the protection, adaptation, and repair options become fewer and less effective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SciencesPo

POLICY BRIEF

N°04/15 SEPTEMBER 2015 | CLIMATE - OCEANS AND COASTAL ZONES

Intertwined ocean and climate: implications for international climate negotiations

Alexandre K. Magnan (IDDRI), Raphaël Billé (Secretariat of the Pacific Community), Sarah R. Cooley (Ocean Conservancy), Ryan Kelly (University of Washington), Hans-Otto Pörtner (Alfred Wegener Institute), Carol Turley (Plymouth Marine Laboratory), Jean-Pierre Gattuso (CNRS-INSU, Sorbonne Universités, IDDRI)

INTRODUCTION

The atmosphere and ocean are two components of the Earth system that are essential for life, yet humankind is altering both. Contemporary climate change is now a well-identified problem: anthropogenic causes, disturbance in extreme events patterns, gradual environmental changes, widespread impacts on life and natural resources, and multiple threats to human societies all around the world. But part of the problem remains largely unknown outside the scientific community: significant changes are also occurring in the ocean, threatening life and its sustainability on Earth.

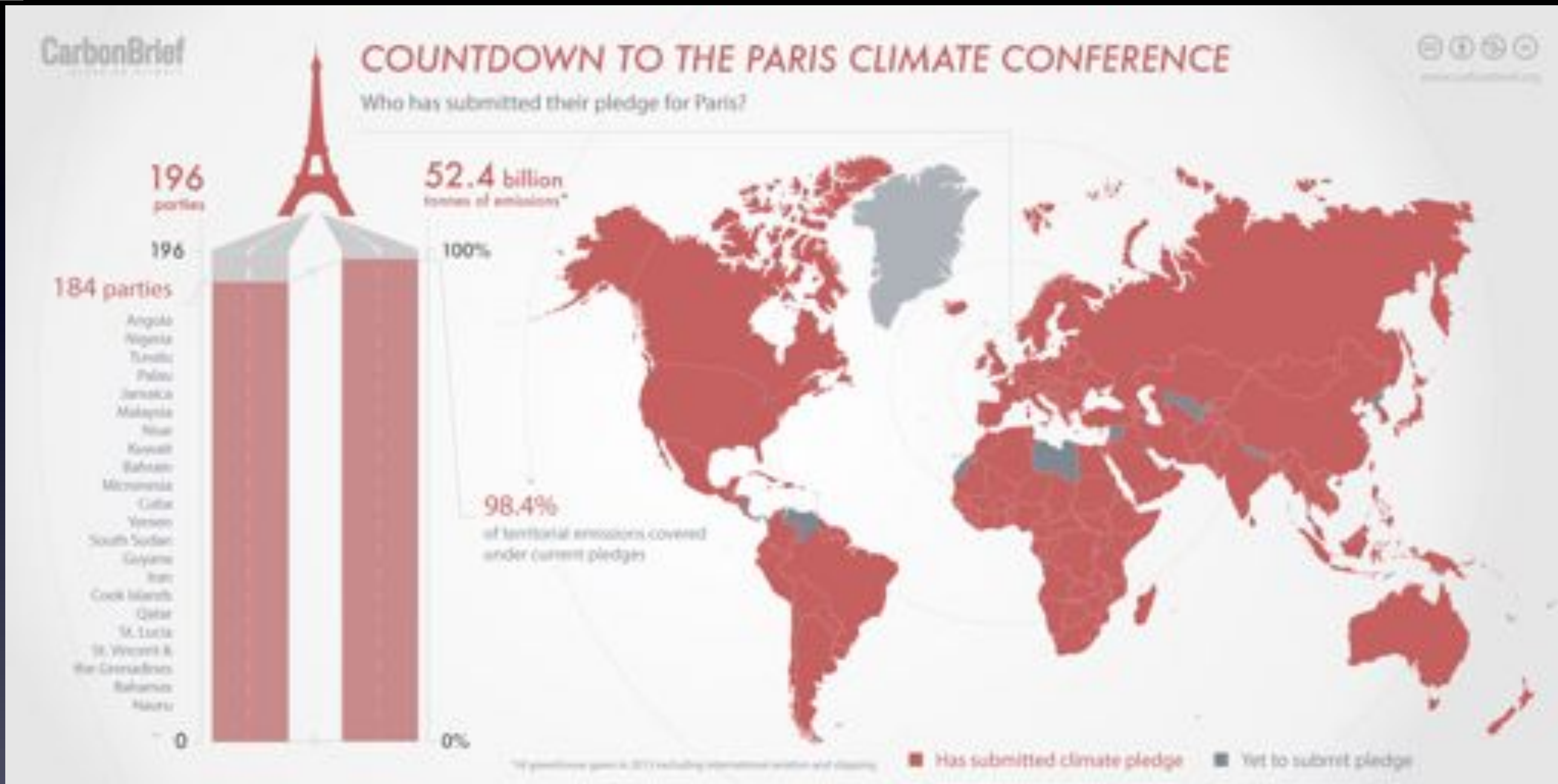
This Policy Brief explains the significance of these changes in the ocean. It is based on a scientific paper recently published in Science (Gattuso et al., 2015), which synthesizes recent and future changes to the ocean and its ecosystems, as well as to the goods and services they provide to humans. Two contrasting CO_2 emission scenarios are considered: the high emissions scenario (also known as "business-as-usual" and as the Representative Concentration Pathway 8.5, RCP8.5) and a stringent emissions scenario (RCP2.6) consistent with the Copenhagen Accord[1] of keeping mean global temperature increase below 2°C in 2100.

KEY MESSAGES

- Climate and ocean are inseparable: the ocean moderates anthropogenic climate change by absorbing significant proportions of the heat and CO_2 that accumulate in the atmosphere, as well as by receiving all water from melting ice.
- This climate-regulating function happens at the cost of profound alterations of the ocean's physics and chemistry, leading to ocean warming and acidification, as well as to sea level rise. These changes significantly affect the ocean's ecology (organisms and ecosystems) and eventually marine and coastal human activities (fisheries, aquaculture, tourism, health...).
- As atmospheric CO_2 increases, possible human responses become fewer and less effective.
- This scientific statement provides further compelling arguments for immediate and ambitious CO_2 emissions reduction at the international level. This conclusion applies to COP21 as well as to the post-2015 climate regime at large.

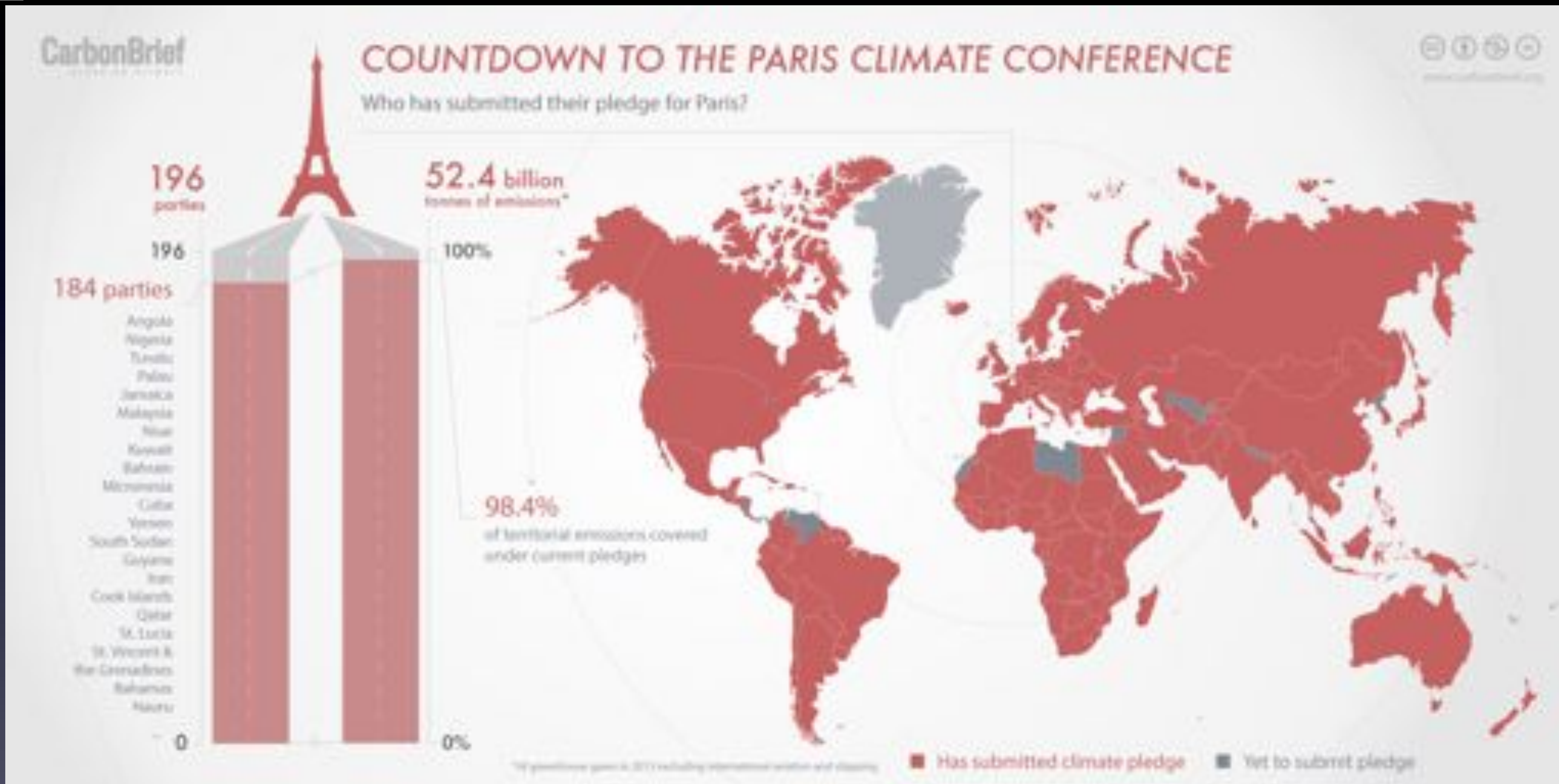
PARIS2015
COP21·CMP11

On the road to COP21 in Paris



The Carbon Brief

On the road to COP21 in Paris



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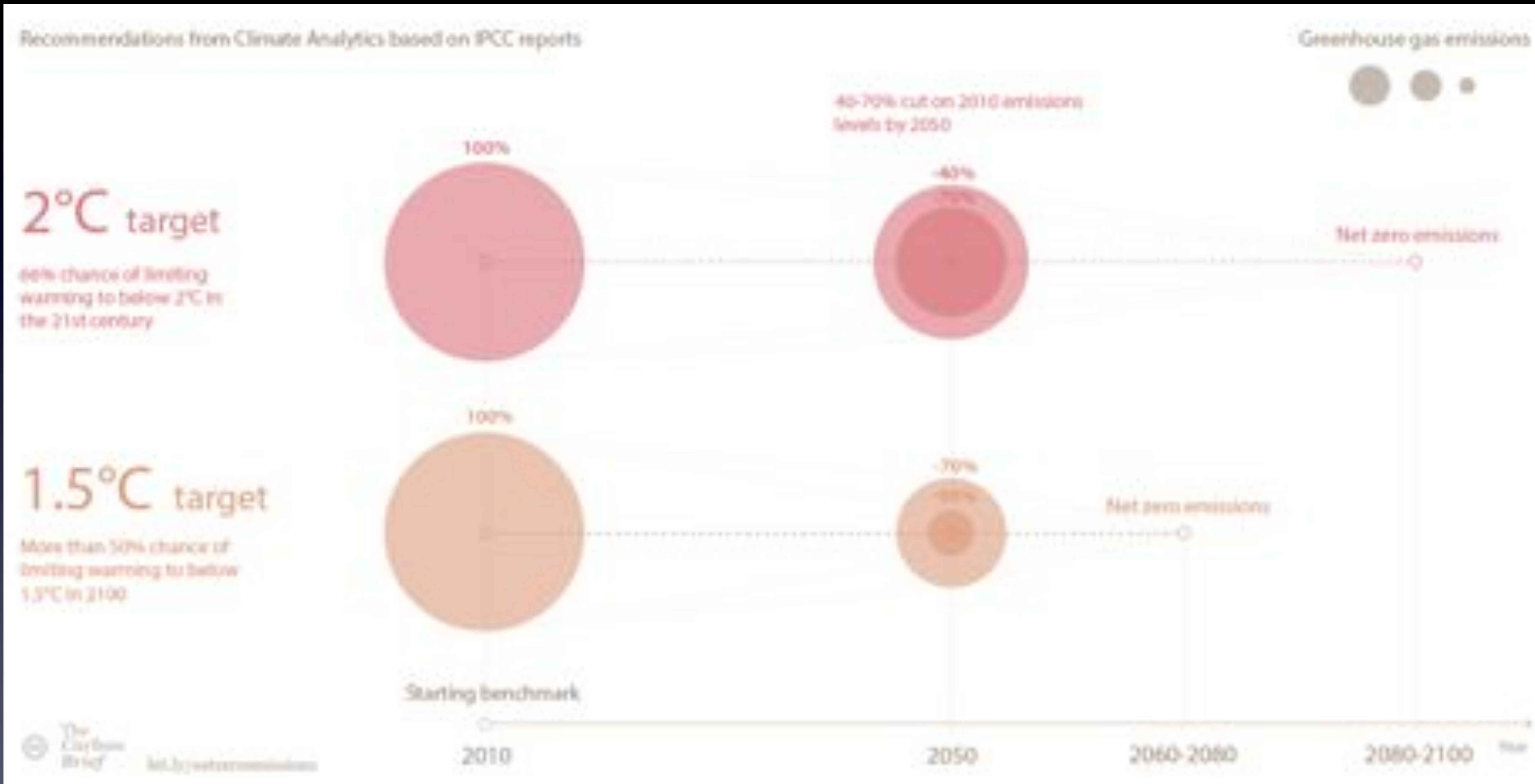
Paris Agreement:

"Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels…"

A timeline for net zero emissions



Risks for ocean and society from different CO_2 emissions pathways

Removed unpublished data

MedSeA
MEDITERRANEAN SEA ACIDIFICATION IN A CHANGING CLIMATE

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Cullettività Territuriale di CORSICA

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